



Ministry of
Northern Development
and Mines

Mines and
Minerals
Division

Ontario Geological Survey
Open File Report 5711

Vermiculite in the Stanleyville Area, Lanark County, Eastern Ontario

1989

©Queen's Printer for Ontario 1989
Printed in Ontario, Canada

MINES AND MINERALS DIVISION

ONTARIO GEOLOGICAL SURVEY

Open File Report 5711

Vermiculite in the Stanleyville Area,
Lanark County, Eastern Ontario

by

A. MacKinnon, P.W. Kingston, and J.S. Springer

1989

This project is part of the five year Canada-Ontario 1985 Mineral Development Agreement (COMDA), a subsidiary agreement to the Economic and Regional Development Agreement (ERDA) signed by the governments of Canada and Ontario.

Parts of this publication may be quoted if credit is given. It is recommended that reference to this publication be made in the following form:

MacKinnon, A., Kingston, P.W., and Springer, J.S.

1989: Vermiculite in the Stanleyville Area, Lanark County, Eastern Ontario; Ontario Geological Survey, Open File Report 5711, 87 p., 13 figures, 12 tables, 3 photos, 3 appendices, and 1 map in back pocket.



Ontario

Ministry of
Northern Development
and Mines

Ontario Geological Survey

OPEN FILE REPORT

Open File Reports are made available to the public subject to the following conditions:

This report is unedited. Discrepancies may occur for which the Ontario Geological Survey does not assume liability. Recommendations and statements of opinions expressed are those of the author or authors and are not to be construed as statements of government policy.

This Open File Report is available for viewing at the following locations:

- (1) Mines Library
Ministry of Northern Development and Mines
8th floor, 77 Grenville Street
Toronto, Ontario M7A 1W4
- (2) The office of the Regional or Resident Geologist in whose district the area covered by this report is located.

Copies of this report may be obtained at the user's expense from a commercial printing house. For the address and instructions to order, contact the appropriate Regional or Resident Geologist's office(s) or the Mines Library. Microfiche copies (42x reduction) of this report are available for \$2.00 each plus provincial sales tax at the Mines Library or the Public Information Centre, Ministry of Natural Resources, W-1640, 99 Wellesley Street West, Toronto.

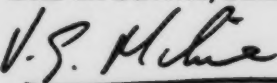
Handwritten notes and sketches may be made from this report. Check with the Mines Library or Regional/Resident Geologist's office whether there is a copy of this report that may be borrowed. A copy of this report is available for Inter-Library Loan.

This report is available for viewing at the following Regional or Resident Geologists' offices:

Southeastern - B.S. 43, Old Troy Road, Tweed, K0K 3J0

Regional Specialist - Box 3000, Highway 28, Bancroft, K0L 1C0

The right to reproduce this report is reserved by the Ontario Ministry of Northern Development and Mines. Permission for other reproductions must be obtained in writing from the Director, Ontario Geological Survey.



V.G. Milne, Director
Ontario Geological Survey

CONTENTS

Acknowledgments	ix
Abstract	xiii
Location of study area	xix
Introduction	1
World vermiculite production	2
Reserves-resources	4
Trends	5
The United States vermiculite industry	5
Producers	5
Vermiculite exfoliating plants	6
The Canadian vermiculite industry	7
Vermiculite exfoliating plants	9
Comparative transportation	10
Tariffs 1988	11
Recent posted prices	11
Economic and quality criteria for a successful Canadian deposit	12
Properties of vermiculite	13
Origin of vermiculite	15
Vermiculite uses	19
Specifications	21
Crude vermiculite	21
Exfoliated vermiculite	24
Substitute material	25
Recent developments	27
Geology of vermiculite deposits	32
Perth study area - General Geology	36
Vermiculite occurrences in the Perth area	41
P. Farrel Property (Norden Vermiculite Ltd.)	41
Olympus Mines Ltd. Property	44
Separation and beneficiation studies - Previous testing	50
Current Test Work	52
Sampling techniques	52
Separation and beneficiation results	53
A. Sample preparation	53
B. Dry beneficiation	54
(i) Magnetic separation	54
(ii) Electrostatic separation	54
(iii) Air tabling	54
C. Wet Beneficiation	54
(i) Flotation	54
(ii) Hydrogen peroxide tests	56
D. Pre-exfoliation method	56
Tests for asbestiform minerals results	57
Geophysical survey	59
Conclusions	63
References	66
Appendix A: Typical vermiculite expanding plant flow plan	74
Appendix B: Cavendish Township - Goshawk Mines Ltd. Property	76
Appendix C: G.H.D. Consultants of Toronto 1969 drill log results	80

LIST OF FIGURES

1. World vermiculite production 1940-1986	3
2. Canadian consumption of exfoliated vermiculite 1968-1987	8
3. One configuration for the Torbed toroidal fluidised bed furnace	29
4. Geologic map of the Rainy Creek Complex near Libby, Montana ...	33
5. Simplified geological map of the Palabora Igneous complex showing the approximate location of the vermiculite open pit	34
6. Geology of the P. Farrell (Norden) property	43
7. Geology of the Olympus Mines Ltd. property	46
8. Ground magnetometer line profiles	61
9. Contour map of ground magnetometer survey	62
10. Flow chart of a typical expanding plant	74
11. Schematic section of a typical vertical furnace	75
12. Geology of the Goshawk Mines Ltd. property	78
13. Drill hole location map	87

LIST OF PLATES

1. Altered dioritic dyke (far right) intruding highly friable, saprolitic pyroxenite (NW pit face)	48
2. Intergrown diopside and tremolite, with talc-oxide alteration .	48
3. Flake edges curl into scroll-like tubes	58

LIST OF TABLES

1. World vermiculite reserves and resources	4
2. 1987 Canadian vermiculite imports by province of clearance	9
3. Principle vermiculite exfoliating plants in Canada	10
4. Tariffs 1988	11
5. Recent posted prices	12
6. Typical physical properties of exfoliated vermiculite	15
7. Size classification of United States crude vermiculite	22
8. Size classification of Palabora crude vermiculite	22
9. Typical chemical analysis of commercial vermiculites	23
10. Specifications exfoliated vermiculite - United States	24
11. Specifications exfoliated vermiculite - South Africa	25
12. Flotation test results	25

LIST OF MAPS IN BACK POCKET

Map 1. Stanleyville vermiculite occurrences (1:10 000 scale)

ACKNOWLEDGEMENTS

The authors gratefully acknowledge the assistance and cooperation of R.K. Collings and J.M. Lamothe of CANMET, the Canadian Centre for Mineral and Energy Technology who undertook trial beneficiation of samples and provided information on previous testing, and of E.J. Chatfield of Chatfield Technical Consulting, Mississauga, who tested samples for the presence of asbestiform fibres at the Ontario Research Foundation. N. Miles of Land Resources Research Center, Agriculture Canada, Central Experimental Farm Ottawa, provided valuable mineralogical data. The authors wish to thank the Mineral Deposits Section, and in particular A.C. Colvine of the Ontario Geological Survey, without whose support this project would not have been possible and offer thanks to D.A. Williams and L.G. Thompson of the Ministry of Northern Development and Mines, Southeastern District, Southern Ontario Region, for informative discussions.

The authors gratefully acknowledge Cye Ross (Canalex Resources Ltd.) for information and access to his property (Olympus Mines Ltd.).

Capable assistance was provided by W.M. Kelly, T. Mullings, R. Renouf, and J. Rudd.

This project was initiated under joint funding by the Resident Geologist's Office, Southeastern District, Southern Region and the Mineral Deposits Section, Ontario Geological Survey, Ontario Ministry of Northern Development and Mines. The project was completed as part of the Canada-Ontario Mineral Development

Agreement (COMDA), which is a subsidiary agreement to the Economic and Regional Development Agreement (ERDA) signed by the governments of Canada and Ontario.

ABSTRACT

Since the discovery of vermiculite at Stanleyville near Perth, Ontario in 1950 by G.C. Bruce of the Industrial Minerals Branch, Ottawa numerous occurrences have been documented. The present investigation examines several of these occurrences (Farrell, Pike Lake and Olympus Mines Ltd. properties) and finds that at the Olympus Mines Ltd. property mineralization consists predominantly of hydrobiotite rather than vermiculite as previous investigators have suggested. X-ray diffraction analysis supports this conclusion. (Hydrobiotite is a layered mixture of biotite and vermiculite in some definite proportion, but is considered a vermiculite for commercial applications).

The Stanleyville-Pike Lake vermiculite occurrences appear to be primarily due to hydrothermal processes, however in the case of the Olympus Mines Ltd. property supergene processes (circulating meteoric water and weathering) may also have influenced mineralization.

Separation and beneficiation studies conducted on chip and core samples at CANMET (Canadian Centre for Mineral and Energy Technology) has shown that ore behavior varies with depth; samples at depth were harder to crush and contained a higher proportion of brittle minerals which resulted in the production of more fines. Favourable results were obtained using a quiet bubble flotation with a 10% hydrogen peroxide solution and tertiary amine as a collector; 95-98% hydrobiotite/vermiculite was recovered. After crushing, screening and exfoliation at 2,000 degrees F, 93% by volume hydrobiotite/vermiculite was

separated by air tabling. Tests performed on the dust fraction of the hydrobiotite/vermiculite ore found only a small concentration of fibrous minerals which consist of cylindrical fibres formed by scrolling of altered flakes of vermiculite (12.1×10^6 fibres/gm or 0.11 ppm mass concentration) and various amphiboles (1.32×10^6 fibres/gm). However, these do not appear to have the characteristics that are of environmental concern.

This report includes a description of world resources, the United States and Canadian vermiculite industry and recent development in processing and product application.

VERMICULITE IN THE STANLEYVILLE AREA, LANARK COUNTY,
EASTERN ONTARIO

A. MACKINNON , P.W. KINGSTON , AND J.S. SPRINGER

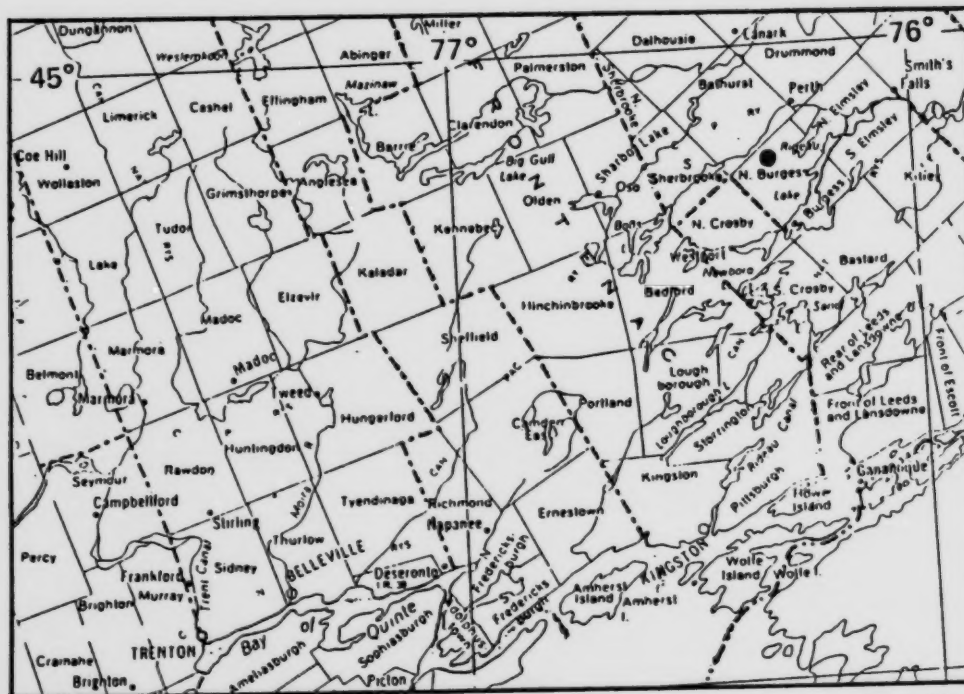
Geologist, Ontario Ministry of Northern Development and Mines,
Southeastern District, Southern Ontario Region

Resident Geologist, Ontario Ministry of Northern Development and
Mines, Southeastern District, Southern Ontario Region

Geologist, Ontario Ministry of Northern Development and Mines,
Ontario Geological Survey, Sudbury, Northeastern Ontario Region

Manuscript approved for publication by V.G. Milne, Director, Ontario
Geological Survey, February 17, 1989.

This report is published with the permission of V.G. Milne, Director,
Ontario Geological Survey, Toronto.



LOCATION MAP

Scale : 1 ; 1 548 000 or 1 inch to 25 miles

INTRODUCTION

Several indicators suggest that a new producer of vermiculite might be successful on the world market. The four major sources, three in the United States and one in South Africa, together produce 93% of the vermiculite consumed by the western world (570,000 tonnes in 1986). North America consumes over 60% of the western world production and since consumption within the United States balances production, the needs of Canadian industries (25,258 tonnes in 1987) and those of the European block are largely dependent on imports from South Africa. Exfoliating plants across the western world are therefore vulnerable to interruptions of the supply and to a price structure firmly controlled by the supplier. Against this background there is both growth in traditional markets and a broadening range of uses for vermiculite.

The Eastern Ontario hydrobiotite/vermiculite occurrences, although extensively tested in the 1960's as aggregate for gypsum plaster, remain largely undeveloped. Now because good domestic market opportunities exist, this project was initiated to investigate the occurrences in the Stanleyville-Pike Lake Area, near Perth, Ontario.

Initially this involved geologic mapping of the Stanleyville-Pike Lake Area and known vermiculite occurrences. Secondly, CANMET (Canadian Centre for Mineral and Energy Technology) conducted separation and beneficiation tests on several prospects. In addition, this report provides a brief discussion of world

resources, the United States and Canadian vermiculite industries and developments in processing and product application.

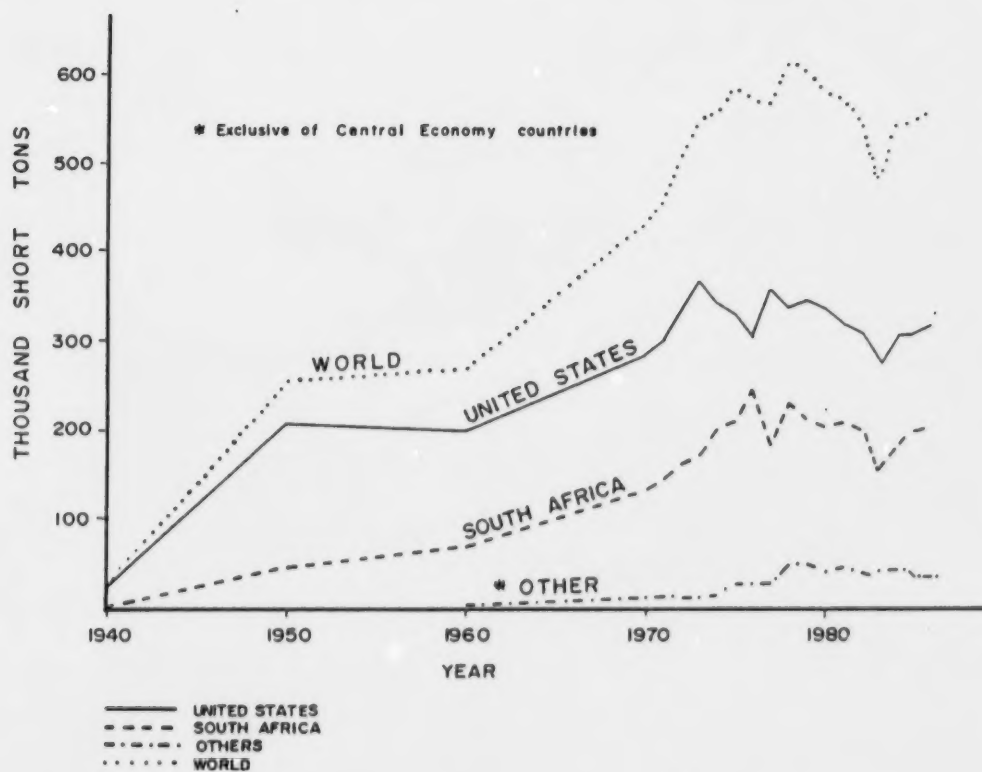
WORLD VERMICULITE PRODUCTION

In 1986, the majority (93%) of the world's vermiculite production (570,000 tons) was supplied by the United States (56%) and South Africa (37%) (Meisinger 1987a). Figure 1, illustrates world production from 1940 through to 1986. Other countries that are presently producing include: Argentina, Brazil, Egypt, India, Japan, Kenya, Mexico and Tanzania; excluded from this list are countries with centrally planned economies.

World production capacity in 1984 was estimated at 650,000 sh tons and forecast for the year 1990 at 700,000 sh tons; United States (450,000 sh tons), South Africa (200,00 sh tons) and rest of world (50,000 sh tons), excluding centrally planned economy countries (Meisinger 1986a).

Most of the United States vermiculite is mined and beneficiated by W.R. Grace & Co. from mines at Libby Montana and Enoree, South Carolina. Several smaller independent producers, also produce from mines near Enoree, South Carolina. The South African vermiculite is produced exclusively by the Palabora Mining Co. Ltd. (PMC) a 38.9% subsidiary of Rio Tinto Zinc Corp. which operates mines at several locations in the Palabora Complex. The marketing is undertaken by two subsidiaries American Vermiculite Corp. of the USA which sells into the Americas, and Mandoval Ltd. of the United Kingdom with responsibility for the rest of the world (principally) though Western Europe (Clarke 1981). South

Figure 1 World vermiculite production 1940-1986



African vermiculite dominates European markets, and although domestic markets are expanding, South Africa remains largely dependent on exports (167,287 tonnes in 1985; Morgan 1987).

Reserves-Resources

The United States reserves are mainly contained within one large deposit, located near Libby, Montana; the United States reserve base includes deposits in South Carolina, Virginia, North Carolina, Texas, Wyoming, Nevada and Colorado.

South African reserves are estimated to contain 80% of the rest of world reserves, excluding the centrally planned economy countries.

Table 1, lists the world vermiculite reserves and resources.

World Vermiculite Resources

Table 1 (million short tons)

	Reserves	Other Resources*	Total Resources
North America (US)	100	25-100	large
South Africa	80	large	large
Rest of World**	20	large	large
Total	200	large	large

(after Beauregard 1982;
Meisinger 1986b, 1987b)

* potential reserves

** does not include countries with centrally planned economies

Vermiculite occurrences in Canada have been reported in British Columbia, and Ontario near Perth and Peterborough.

Vermiculite has also been reported associated with carbonatites in Northern Ontario ie. Pairie Lake Carbonatite, Thunder Bay District (Kretschmar 1983, Sage 1987).

Trends

Meisinger (1986a) states that "world reserves of vermiculite concentrate are more than adequate to meet estimated cumulative demand, 9.8 million tonnes (10.8 million tons) over the forecast period, 1983-2000." The demand for vermiculite is expected to increase at an average rate of 2% through 1990. Transportation costs will continue to limit the size of the market as well as vermiculite's competitive position with respect to other mineral commodities (Meisinger 1987b). However, recent concern (in the United States) over the presense of asbestiform minerals in vermiculite products in the United States and the gradual depletion of South African reserves may eventually result in shortages worldwide.

THE UNITED STATES VERMICULITE INDUSTRY

Producers

The United States produced 287,600 tonnes (317,000 tons) of vermiculite concentrates in 1986; domestic production was estimated at 294,800 tonnes (325,000 tons) in 1987 (Meisinger 1987a). Three companies produced the majority of the United States vermiculite, G.R. Grace & Co., Patterson Vermiculite Co. and Strong-Lite Products Corp. (Carolina Vermiculite Co. Inc.); W.R. Grace is the largest and dominates domestic markets, both in terms of production and mineral exfoliation. W.R. Grace has a

production capacity of 227,000 tonnes (250,000 tons) from open pits at Enoree, South Carolina and Libby, Montana. Patterson Vermiculite Co. and Carolina Vermiculite Co. Inc. also operate mines at Enoree, South Carolina. Other small producers include: Micro-Lite Inc. at Buffalo, Kansas; Virginia Vermiculite Ltd. in Louisa, Virginia; Steetly Resources Inc. at Millerville, Ohio; and Western Resources Co., at Corvallis, Montana. Production is primarily consumed by domestic markets, with exports confined to Canada and Mexico. Exports to Canada in 1986 were estimated to be 25,000 short tons, representing only 8% of total sales (Meisinger 1986a, 1987a).

Vermiculite Exfoliating Plants

Exfoliated vermiculite, because of its low density and high volume, is expensive to transport. Therefore, crude vermiculite is beneficiated into well-defined grades and shipped for exfoliation to plants serving specific geographical market areas. In 1986, crude vermiculite was exfoliated at 41 plants in 28 states (Meisinger 1987a); the majority of these (29 exfoliation plants in 24 states) were either operated by, or have licensing agreements with, the Zonolite Division of W.R. Grace & Co. More than one half of the domestic exfoliating plants in the United States are small, producing less than 4,500 tonnes (5,000 tons) per annum (Meisinger 1986a).

THE CANADIAN VERMICULITE INDUSTRY

The markets for crude vermiculite (non-exfoliated) are small, and are restricted to a few special markets. In its expanded form, however, it has a wide range of applications and, in the past 20 years, the range of uses has increased markedly. Canada has no crude vermiculite production; graded vermiculite is imported from the United States and South Africa. In 1987, Canada imported 25,258 tonnes, valued at \$4,202,955; imports from the United States totaled 20,859 tonnes (valued at \$3,743,661) and South Africa 3,340 tonnes (valued at \$527,352) (statistics Canada 1987). Imports by province of clearance for 1987 are listed in Table 3; it should be that the noted province of clearance does not necessarily represent the region of end use. In 1987, 48.7% of the exfoliated vermiculite in Canada was used for horticultural applications, miscellaneous uses (38.7%) and loose fill insulation (12.6%). However, there may be a greater proportion used for loose fill insulation than statistics indicate (Oliver Vagt, Mineral Policy Sector, Energy Mines and Resources, personal communication, 1989). Figure 2, illustrates trends in consumption of exfoliated vermiculite in Canada from 1968 through 1987. Since 1985 there has been a marked increase (from 11.8 to 38.7%) in miscellaneous uses of vermiculite, this is probably due largely to the use of vermiculite as an asbestos replacement in refractory and friction product applications.

Markets exist for vermiculite concentrates of approximately 24,500 tonnes to 29,000 tonnes/year, plus 7,300 tonnes/year of expanded vermiculite for a favourably located Ontario deposit,

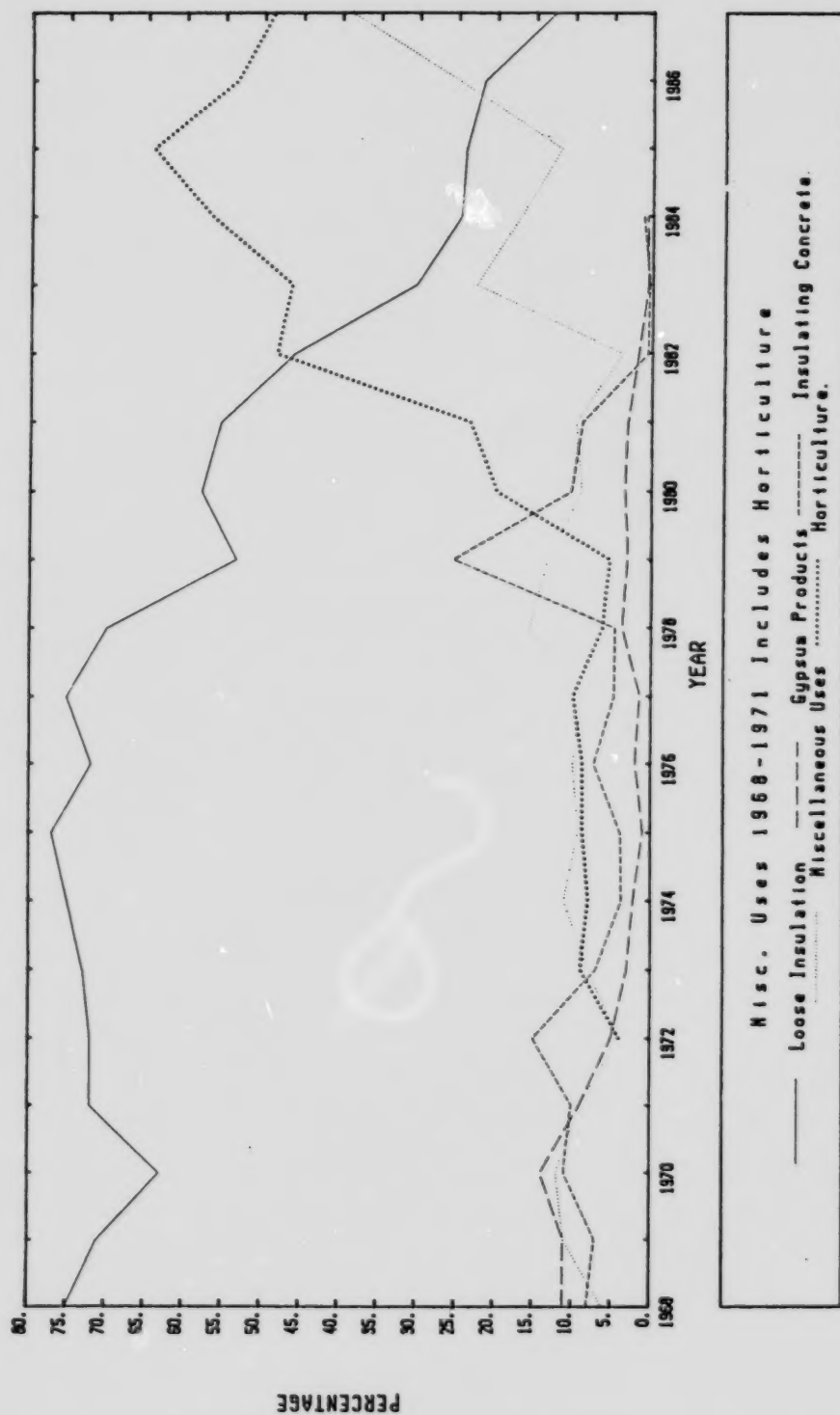


Figure 2, Canadian consumption of exfoliated vermiculite 1968-1987 (after Canadian Minerals Yearbooks 1970-1988)

such as at Perth, because of high transportation costs of importing vermiculite (Beauregard 1982).

THE CANADIAN VERMICULITE INDUSTRY

Table 2

	TONNES	VALUE (\$)
NFLD	280	28,550
N.S.	363	50,811
QUE.	8,304	1,315,085
ONT.	9,124	1,598,912
MAN.	1,409	259,827
ALTA.	2,546	442,849
B.C.	3,232	506,921
TOTAL	25,258	4,202,955

(from Statistics Canada, 1988)

Vermiculite Exfoliating Plants

Canada has seven vermiculite exfoliating plants. Two are located in each of Ontario, and Quebec, with one in each of Manitoba, Alberta and Nova Scotia. These exfoliation plants are listed in Table 3.

In North America, most exfoliating plants are tied to the major producer, W.R. Grace; either through ownership or licencing agreements: Beauregard (1982) reports that "a somewhat less stringent agreement exists between Palabora Mining, the South African producer, and Vermiculite Insulating, which allows the company to purchase from W.R. Grace occasionally."

Table 3, illustrating the principle vermiculite exfoliating plants in Canada.

<u>Operating Company</u>	<u>Province</u>	<u>City</u>
V.I.L. Vermiculite Inc.	Quebec	Lachine
Domtar Inc.	Quebec	Montreal
W.R. Grace & Co. of Canada Ltd.	Ontario	Ajax
	Ontario	St. Thomas
	Manitoba	Winnipeg
	Alberta	Edmonton
Annapolis Valley Peat Moss Co. Inc.	Nova Scotia	Berwick

(from Vagt 1988)

Comparative Transportation

As is the case with many industrial minerals, vermiculite is very sensitive to transportation costs.

In 1986, the average value for exfoliated vermiculite sold and used in the USA was \$210.00 (US) per short ton, F.O.B. exfoliating plant (Meisinger 1987a).

Beauregard (1982) estimated prices for crude vermiculite landed at various ports are listed below:

Libby crude vermiculite	- Montreal	\$160-220/sh ton
	- Toronto	\$152-212/sh ton
South African crude (micron quality)	- Montreal	\$190/sh ton

To assess the competitiveness of one of Ontario's more promising deposits, Beauregard (1982) has costed transportation by various means from Libby, Montana (W.R. Grace's open pit operation) and from Perth, Ontario to various exfoliating plants in the States

or provinces around the Great Lakes. It is apparent that for 60% of the destinations costed, a product-of-comparable F.O.B. price could be delivered more cheaply from Perth.

If trucking is the chosen transport method, in 1982, delivery to Montreal from Perth for example, cost \$28-40/ton compared to \$75-80/ton from Libby, Montana to Montreal. Transportation from Palabora, South Africa, to Montreal on the same date was estimated to cost \$101 Cdn/ton (Beauregard 1982).

Conversely, shipping Ontario vermiculite from Perth via Montreal to Rotterdam or Antwerp was calculated at less than \$80 Cnd/ton, a price that could compete in terms of transportation with South African vermiculite. For the journey Montreal to U.K., transportation was reckoned at \$73-79Cdn/ton (Beauregard 1982).

Tariffs 1988

Table 4

Non-Exfoliated

No. 2530.10.10

Duty Free

Exfoliated

No. 6806.20.00

Canada

United States

Most Favoured Nation

10.2%

4.9%

General Preferential

6.5%

Free

(from Statistics Canada 1988)

Recent Posted Prices

Price quotations (Table 5) are taken from the Industrial Mineral Magazine, December, 1988 and it should be noted that price will

vary according to type, source, quality, quantity, and application of the vermiculite.

Table 5

South African, bulk, short ton, FOB Rotterdam	\$115.00 -- \$178.00 U.S.
Raw, FOB U.S. plant, bulk, sh. tons	\$ 65.00 -- \$135.50 U.S.
South African, crude bulk FOB barge, Gulf coast, sh. tons	\$105.00 -- \$170.00 U.S.

(from Anonymous 1988)

Economic and Quality Criteria For A
Successful Canadian Deposit

Any Canadian deposit seeking to compete with the U.S. or South African ores would need

- to grade more than 30% vermiculite, although deposits of exceptional quality can be workable at 20%;
- to contain as little other micaceous material (biotite or phlogopite) as possible in order to simplify separation; impurities should not exceed 10% and preferably be much less.
- to be large enough to mine by open pit methods at a rate of 30-50,000 tons per year, a tonnage which would cover the Canadian market and that of some of the nearer States in the U.S.;
- to contain predominantly large flake, as small flake markets are already well-supplied;
- to be located as close to user markets as possible.

The material itself would require

- to have a bulk density of 4-10 lbs/cu. ft. (.064-.160 g/cc) after exfoliation;
- to yield an expansion product that is not brittle and does not decrepitate during exfoliation;
- high absorptive property for use in horticulture.
- to become a product as pale as possible in colour;
- to use as little energy for exfoliation as existing crude vermiculites;
- to contain minimal amounts of fibrous or dusty materials in order to reduce possible health hazards.

PROPERTIES OF VERMICULITE

Commercial vermiculite refers to a family of related minerals sharing the common properties of being all secondary, monoclinic, hydrated, ferromagnesian aluminosilicates, with the ability to exfoliate upon rapid heating (Wilson 1981). Low density, chemical inertness, high fluid absorbability, high cation exchange capacity, resistance to fire, and good thermal and acoustic insulation qualities are among the unique properties of vermiculite that are utilized by a wide variety of industries such as construction, engineering, metallurgy, horticulture, and agriculture.

The variations in chemical compositions, colours and physical properties of vermiculite are partially due to the progressive nature of the alteration. At Stanleyville this fact was evident in the field and in thin sections, and is reflected in its

behaviour on processing. The colour varies from shades of brown, red-brown, and green to almost black, with true vermiculite being a light silvery or golden tan colour. The lighter coloured varieties seem to be more highly hydrated. Flakes are inelastic, usually warped or bloated in appearance, with the hardness varying between 1.5 in true vermiculite to 2.5-3 in unaltered mica. The expanded product is very light, with densities varying between 5 and 10 lbs/cu. ft. (Bush 1976). Common exfoliation values are between 8 and 15 times but ideally may reach a maximum of 30 times (Deer et al 1980).

Since vermiculite is seldom used in the unexfoliated form, typical physical and chemical properties of exfoliated vermiculite are listed in Table 6 (Anonymous 1977; Roskills Information Services 1986).

Table 6

Typical Physical Properties of Exfoliated Vermiculite (SI units)

Loose bulk density (crude)	640-960 kg/m ³
Loose bulk Density (exfoliated)	56-192 kg/m ³
Sintering temperature	approx. 1,260°C
Melting Point	approx. 1,315°C
Specific heat capacity	840 j/kg°C
Specific gravity	2.6
Thermal diffusivity	0.025 Sq. ft./hr.
Thermal conductivity	0.062-0.065 W/m ² °C
Specific heat at 0 deg F.	0.20 Cal/gm/deg. C
Specific heat at 300 deg F.	0.24 Cal/gm/deg. C
Cation exchange capacity	
Vermiculite ore (S. Caroline)	70 milli-equivalents/100 g
Vermiculite ore (Montana)	35 milli-equivalents/100 g
Exfoliated vermiculite (S. Carolina)	20-60 milli-equivalents/100 g
Exfoliated vermiculite (Montana)	20-30 milli-equivalents/100 g

ORIGIN OF VERMICULITE

Considerable controversy has arisen, through the years, over the origin of vermiculite. Circulating meteoric waters and hydrothermal alteration, either acting individually or together, are the predominant formational processes suggested for the genesis of vermiculite. The formational process is important to the economic potential of the deposit since vermiculite formed by meteoric water would be confined to the shallow zone of

circulation where as the hydrothermal vermiculite may reasonably continue to depth.

The pyroxenite-hosted deposit at Libby, Montana leaves little doubt as to its hydrothermal origin, with vermiculitization of the biotite occurring to a depth of a 1,000 feet or more (Harben and Bates 1984). Both theories have been suggested for the vermiculite at Palabora, South Africa but a meteoric origin was finally accepted as vermiculite gradually grades into unaltered phlogopite at various depths between 120 and 150 feet. The deposit at Enoree, South Carolina is an example of vermiculite formed by both processes (Wilson 1981).

Barshad (1948) and Hoadley (1960) describe the process of vermiculitization as follows:

"Alteration of mica to vermiculite is accomplished by a slight rearrangement of the atoms within the lattice layers and by replacement of the K^+ interlayered ions by other cations, generally Mg^{2+} , or Mg^{2+} plus Ca^{2+} ions in natural vermiculite, by means of base exchange. This exchange process is accomplished by the introduction of varying amounts of water molecules between the lattice layers, the amounts being determined in any one case by the kind of exchangeable ion present. Oxidation of Fe^{2+} to Fe^{3+} accompanies hydration, with partial replacement of Si^{4+} in the silicon-oxygen tetrahedron."

Oxidation is marked by a colour change from brown to red, as fine-grained hematite precipitates in the space between the double layers in the mica sheet.

At Stanleyville, this feature was observed on the Farrell Property and numerous other localities by Hoadley (1960), by Guillet (1962), and by the present authors. Locally, light to dark green vermiculite was observed either alone or intermixed with the hematitic variety. The colour variation may

reflect fluctuations of the water table, with oxidizing conditions producing a red colouration and reducing a greenish. Hoadley (1960) observed progressive changes from brown to green in one specimen indicating the green colouration developed after hydration of the phlogopite.

Three general groups of rocks in the Perth study map area play a significant role in the development of vermiculite and this is best seen in a mineralized zone on the Olympus Mines Ltd. property. These units are: the Grenville Supergroup metasedimentary rocks, Late Precambrian intrusive rocks, and Paleozoic rocks.

The host for mineralization (hydrobiotite/vermiculite) was probably originally a phlogopite-rich dolomitic marble (seen at the Farrell Property, and throughout the study area). Late Precambrian acidic intrusions have migmatized the country rock and produced solutions which altered the marble to pyroxenite, in the case of the Olympus Mines Ltd. property. Recrystallization due to the addition of silica either as SiO_2 or as silicates may have resulted in increased permeability and brittleness which could have permitted the circulation of hydrothermal fluids. Alternatively the close proximity to the Middle Ordovician erosion surface may have influenced mineralization where the permeable zone has acted as a conduit for later fluid movement (Miles and Springer 1983a). To what degree each of these processes influenced mineralization is presently uncertain. Regardless, the co-existence of phlogopite, hydrobiotite,

smectite, corrensite and chlorite (observed in samples from the Olympus Mines Ltd. property), is representative of various stages of the transformation sequence of the anhydrous mineral (phlogopite) to hydrous ones (N. Miles, Mineralogist, Agriculture Canada, Ottawa, personal communication, 1989). DeKimpe and Miles (1988) state that the formation of corrensite at the expense of phlogopite implies (a) loss of inlayer K⁺ from phlogopite (b) formation of an expanding mineral with hydrated interlayer cations and (c) chloritization of alternate layers of the expanding mineral. Therefore the presence of corrensite and allietite (talc-smectite) as the major clay-sized constituent implies over-alteration of the Olympus ore to these phyllosilicates (Miles and Springer 1988b). Allietite in the highly altered saprolitic zone near surface suggests further supergene alteration due to weathering.

At the Pike Lake occurrence, on concession 9, lot 17, North Burgess township, vermiculitization was noted in a pit 4-5 metres below the surface of a phlogopite body, immediately adjacent to a syenitic feldspathic stringer. Completely unaltered phlogopite occurs a few feet on either side of the stringer and immediately below the soil cover, leaving little doubt as to a hydrothermal origin for the vermiculite. Corrensite occurs in a nearby roadcut on Hwy. 10, where it was formed at the expense of phlogopite by hydrothermal alteration (Miles and DeKimpe, 1988). DeKimpe and Miles (1987, 1988) states that corrensite is frequently formed in the dolomitic marbles of southeastern Ontario by hydrothermal alteration.

The Paleozoic rocks, although not genetically important to the mineralized zone, are still an essential component. This thin unit preserved the mineralization capping the soft altered pyroxenite during glaciation until the waning phase of glaciation scraped off the last remnants of Paleozoic cover, exposing the pyroxenite to post-glacial surficial weathering.

VERMICULITE USES

Vermiculite is largely used in the exfoliated form; markets are primarily ultra-lightweight aggregates in the construction industry, and horticulture. The demand for crude vermiculite (non-exfoliated) is very limited, restricted to only a few specific uses, such as, fillers in fire resistant wallboard, loose fill cover over molten metal, slag coagulant, and in oil well drilling (Beauregard 1982; Power 1986).

Marketing of exfoliated vermiculite in well-defined grades has proven to be useful in construction, agriculture and other industries. Generally the large flake grades are used in loose-fill insulation, the medium-sized for various bonded aggregates and the fine-grained vermiculite for chemical and agricultural carriers, in refractory products, and as a filler and/or extender in paints, plastics and rubber (Beauregard 1982; Power 1986). Vermiculite is used in construction where lightweight, thermal insulation and acoustical qualities are of particular importance, such as for roof decks.

Exfoliated vermiculite serves a wide variety of applications, some of which are listed below (W.R. Grace and Co. 1971).

Construction Industries

Gypsum plaster fireproofing	Preformed concrete roof tiles
Concrete fireproofing	Cold storage insulation
Loose fill insulation	Underground pipe insulation
Masonry wall insulation	Sound conditioning
Insulating concrete roof decks and floors	

Agriculture

Fertilizer conditioners	Mulch
Hatchery litter	Soil conditioners
Cutting beds	Propagation of seed
Plant, nutrients	Carriers of insecticides, herbicides, fungicides, fumigants
Soil modification--bulking agent	Anticaking agent for fertilizers, for encapsulating seeds, and for poultry litter

Metallurgical

Carrier for additives	Lubricant for extrusion and drawing
Mold linings	Insulation over molten zinc and lead

Chemical

Protective coatings	Molecular sieve
Absorbent	Carrier
Diluant	Cryogenics

Ceramic

Castable insulation

Insulating fire brick

Building blocks

Pre-fab chimneys

General

Packing material

Disposal of nuclear wastes

Transportation of hot ingots

Insulation of liquid air
storage vessels

Insulation of household
appliances

Fillers in paints, plastics
and rubber

Vermiculite cement compounds are used as an incombustible sealant in mines, where it is sprayed on, and adheres to most substrates. It is particularly useful as a fire retardant coating on structural steelwork in oil refineries and chemical plants (Mandoval 1972).

SPECIFICATIONS -- CRUDE VERMICULITE

There are as yet no Canadian Standards Association (CSA) specifications for the lightweight aggregates. Production and application are based on the American Society for Testing and Materials (ASTM) designations as follows; ASTM Designations C 332-66 - Lightweight Aggregates for Insulating Concrete; C 330-75a-Lightweight Aggregates for Structural concrete; and C331-69-Lightweight Aggregates for Concrete Masonry Units (Vagt 1988).

Size classification of U.S. crude vermiculite

W.R. Grace & Co. grades domestic vermiculite on the basis of bulk density and size as follows:

Table 7

W.R. Grace designation	Tyler Mesh	Approx. equivalent max. size in inches	Density (lb/cu)
1	3-10	1/4	4 to 7
2	8-14	3/32	4 to 8
3	10-35	1/16	5 to 9
4	28-65	1/32	6 to 10
5	35+	1/64	8 to 11

(after Anonymous 1977; Meisinger 1980)

Size Classification of South African crude vermiculite

The grading system for South African (Palabora) vermiculite, in accordance with recommendations by the International System of units, is based on the metric system as follows:

Table 8

Palabora designation	Old grade number	Size range (mm)	wt% passing 150 seive
Premium	6	-16 + 8	90-100
Large	4	- 8 + 4	90-100
Medium	3	- 4 + 2	90-100
Fine	2	- 2 + 1	90-100
Superfine	1	- 1 + 0.5	80-100
Micron	0	-0.5 + 0.25	50-100

(after Clarke 1981)

Palabora Mining Co. Ltd. particle size is coarser than W.R. Grace & Co., Palabora measures grades with maximum sizes on the square where as W.R. Grace measures the diagonal.

Table 9 Typical chemical analyses of commercial vermiculite

	<u>Libby</u> <u>Montana</u> %	<u>Encoree</u> <u>S. Carolina</u> %	<u>Palabora</u> <u>South Africa</u> %
SiO ₂	38.64	38.66	39.37
MgO	22.68	20.04	23.37
Al ₂ O ₃	14.94	17.36	12.08
Fe ₂ O ₃ (Total Fe)	9.29	8.45	5.45
Na ₂ O			.80
K ₂ O	7.84	5.24	2.46
BaO			0.03
CaO	1.23	0.75	1.46
Li ₂ O			0.03
Cr ₂ O ₃	0.29	0.50	NIL
MnO	0.11	0.12	0.30
P ₂ O ₅	Trace	Trace	0.15
TiO ₂			1.25
S	Trace	Trace	0.18
F			0.25
Cl	0.28	0.52	0.02
CO ₂			0.60
H ₂ O	5.29	8.71	
Loss on ignition at 850°C			14.24
TOTAL	100.59	100.36	102.04

(after Myers 1960, Anonymous 1977)

SPECIFICATIONS EXFOLIATED VERMICULITE

Table 10

U.S. Expanded Vermiculite

Grade No.	Sieve size U.S.	Cumulative % retained		Bulk Density (ASTM C-29) lb./cu.ft.	End Uses
		Max.	Min.		
1	3/8	10	0	4-7	Loose-fill house insulation.
	4	60	30		
	8	95	65		
	16	100	85		
2	4	5	0	4-8	Loose-fill refri- gerator insulation, concrete aggregate.
	8	80	20		
	16	99	75		
	30	100	90		
3	8	10	0	5-9	Plaster aggregate.
	16	60	20		
	30	95	65		
	50	98	75		
	100	100	90		
4	16	5	0	6-10	Filler, insecticide, carrier, extender for paint.
	30	65	15		
	50	98	60		
	100	100	90		

* Grades 1, 2 and 3 all find applications in agriculture.

(from Anonymous 1977)

Table 11

South African Expanded Vermiculite

<u>Grade</u>	<u>Old Number</u>	<u>Size mm</u>	<u>Density lb./cu.ft.</u>	<u>End Uses</u>
Premium	6	16 down	3 1/2 - 4 1/2	Loose-fill house insulation.
Large	4	8 down	4 - 5	
Medium	3	4 down	4 1/2 - 5 1/2	Concrete Aggregate.
Fine	2	2 down	5 1/2 - 7	Plaster aggregate.
Superfine	1	1 down	6 1/2 - 9	Rooting medium for tobacco seedlings.
Micron	0	0.5 down	6 1/2 - 10	

(Anonymous 1977)

SUBSTITUTE MATERIAL

Expanded perlite and exfoliated vermiculite both benefit from a very low bulk density and are therefore able to substitute for each other in most applications. The choice of one mineral over the other, apart from price, is often the source of supply. Here perlite has an added advantage with its wide geographical production base in North and Central America, the Mediterranean, Eastern Europe and the Pacific Basin, while vermiculites production is primarily restricted to South Africa and the United States. Perlite is slightly cheaper and therefore generally favoured in most construction applications, capturing much of the lightweight aggregate markets in the United States and Europe (Power 1986).

In plasters, a traditionally vermiculite market, perlite is now favoured particularly where lightweight and good plastering

properties are required. However, vermiculite is preferred where fire-proofing or increased adhesion is desired (ie. sprayed on mine walls as a sealant and fire proofing). Other more dense but less costly substitutes in concrete and plaster include expanded clay, shale, slate or slag.

Vermiculite's fire-retardancy characteristics are utilized by the refractories industry, where vermiculite and selected binders are compressed and formed into blocks, boards or speciality shapes for use as "back up" or hot face applications in the temperature range 1100-1200°C. While the majority of vermiculite is used in these preformed products, it is also the principal lightweight aggregate in refractory concretes such as castables and ramming mixes (Power 1986). Vermiculite is finding greater acceptance as an asbestos alternative in many refractory and friction applications.

Power (1986) states that: "While vermiculite excels in the high temperature applications, perlite is the preferred medium for use at the other end of the temperature spectrum. Perlite insulation is particularly important in the cryogenic insulation of gas storage tanks and sea going vessels where gases such as oxygen, nitrogen, methane, propane, ethylene and ammonia have to be kept in a liquid state at extremely low temperatures." Perlite is preferred because of its low moisture retention compared to vermiculite, since any uptake of moisture increases thermal conductivity and significantly reduces the insulation properties of this layer. Although perlite is preferred over vermiculite in this particular application, it should be noted that use of

wool rock and plastic foams are becoming increasingly more competitive.

It is in the insulation industry, that vermiculite has experienced its most significant set backs. Here vermiculite has had to compete with numerous cheaper materials such as, mineral wools, polystyrene foam, polyurethane foam, wood fibre, milled newsprint or wood pulp treated with fire resistant chemicals, perlite and glass fibre.

In horticulture, vermiculite's property of cation exchange, and perlites inherent porosity, has resulted in a complementary relationship between the two minerals. As a result, the mineral selected depends on the degree of water retention, nutrient induction, soil porosity and root anchorage required. Other substitutes used in horticulture include peat, sawdust, bark and other plant materials and synthetic soil conditioners.

Other non-constructional uses in which vermiculite and perlite compete include: fillers in paints and plastics, abrasive, oil absorbers, and animal feed additives.

RECENT DEVELOPMENTS

In this section developments in processing and product application will briefly be discussed. The market for fire retardant boards and panels in recent years has experienced significant growth. These products are manufactured by a variety of techniques. One method is similar to that employed for wood chipboard in which exfoliated vermiculite and inorganic and/or

organic binders are mixed, then compressed and cured into the required shape. This is then used for ceiling tiles, building and marine panels, fire protection cladding and high temperature insulation boards. An alternative method employs the use of a wet slurry in which the exfoliated vermiculite is blended with calcium silicate binders and other additives. "The slurry is subsequently dewatered and cured by the Fourdrinier/Magnani process for making wood fibre and asbestos boards etc.." (Dickson 1982)

The Torbed process is a recent technological advancement in thermal processing that was developed by Torftech Ltd. in Britain, which if proven to be cheaper or more efficient may convert what is presently uneconomical into a viable deposit. The process resembles no existing single process but incorporates three established techniques in combination ie. hovercraft, fluidised bed, and cyclone (Dodson 1986). Figure 3, illustrates the Torbed toroidal fluidised bed furnace. Advantages Clarke (1981) cites are high mass/energy transfer rates that minimize processing time, rapid loading/unloading of material enabling a continuous automated batch process, low fluid pressure drop across the bed thus allowing for treatment of gas, heat recovery and other high volume gas treatment processes, close temperature control, compactness, and installation of microprocessor in few hours. The method is compact, mobile and energy efficient.

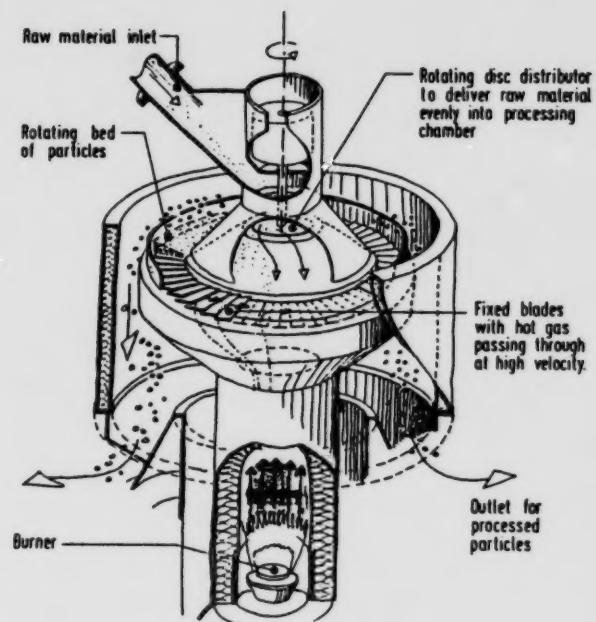


Figure 3, One configuration for the Torbed toroidal fluidised bed furnace (after Dodson 1986; Torftech 1983, 1984).

New applications are especially important to the Stanleyville area as this vermiculite is overly friable for most current uses. Products currently the subject of experimentation are vermiculite-based paper, fabrics, and foams, and silicon-based products.

Dr. Denis Ballard (Imperial Chemical Industries PLC Research Laboratories in Britain) conducted research into silicon-based products; these products mimic plastics, one of which may be an effective substitute for asbestos. Potential applications include fire-resistant facings for organic foams, wall paper and roofing installations, high temperature gaskets and expansion joints in furnaces and boilers, heat resistant interlayers in domestic appliances, and wrapping for electrical cables in control systems of chemical plants (Globe and Mail 1984).

The conversion of vermiculite to a usable product is accomplished through the following series of steps. The ore is first refluxed for approximately 30 minutes in a saturated solution of sodium chloride in which the divalent magnesium ions are replaced by monovalent sodium ions. The leached magnesium ions and excess sodium chloride are washed away. A further refluxing by 2M n-butylammonium chloride for 30 minutes, results in monovalent butylammonium ions substituting for the sodium ions. The excess ions are again washed away. During this second washing the ore becomes hydrated and expands up to 30 times producing a water based gel in which the interlammellar spaces are filled with water. Refluxing with sodium chloride is not essential but greatly reduces processing time (Ballard and Rideal 1983). The

gel is then sliced into a soup of thin plates, five to twenty thousandths of a millimeter in thickness. These plates are so flexible that they will wrap around fibres dipped in the soup (Globe and Mail 1984).

The coatings are stabilized during the final stages of drying by exchanging n-butylammonium ions with any multivalent ion: e.g. Mg^{2+} , Ca^{2+} , Zn^{2+} , or ammonium ion (Ballard and Rideal 1983).

Vermiculite films can be formed around fibres or on metal surfaces; some films are even more resilient than films obtained from organic polymers such as, polyethylene and polyethylene terephthalate (PET).

ICI research in Britain has extended glass fibre into applications which previously required the use of asbestos-containing materials or even of costly silica or ceramic fibre products. Glass fibre papers and textiles are produced by coating glass fibres. The coatings are dispersed in slurry that is applied to the fabric by automatic or impregnation machinery (ICI pamphlet, Fortress 'T'). Experimentation conducted by ICI, demonstrated the ability of these coatings to act as a thermal barrier. For example, uncoated glass fibre possessed a maximum operating temperature of $550^{\circ}C$, however when a vermiculite coating was applied, the globules were retained and prevented from flowing even when the glass was completely melted in a furnace at $1200^{\circ}C$. Coatings on aluminum foil, similarly, prevented melting when subjected to high temperatures (Ballard and Rideal 1983). Materials coated with the films are virtually

flame proof because heat is conducted away 7 times faster than through (Globe and Mail 1984). These properties make vermiculite appear to be an economic and preferable alternative to asbestos, without the associated health hazards.

Another potential application of vermiculite suspensions, currently the subject of experimentation at ICI, is vermiculite-based foam. Foams are readily produced by introducing small air bubbles into a suspension with a maximum solids content, while still retaining flow characteristics. Just prior to formation of the foam, water is added as a stabilizing agent. Experiments determined that the addition of magnesium oxide produced foams with the highest compressive strengths due to the formation of crystal bridges between lamellae (Ballard and Rideal 1983).

Production of these vermiculite-based products is presently being undertaken on a pilot plant level, and various industries are currently studying their use. Research in the near future will probably extend the range and uses of these products. In summary, careful analysis of a deposit is essential if it is to be exploited to its full potential.

GEOLOGY OF VERMICULITE DEPOSITS

Worldwide, virtually all vermiculite deposits are associated with either mafic and ultramafic igneous or metamorphic rocks that have been invaded by silicic magmas or carbonatites.

Harben and Bates (1984) distinguished three general types of deposits: (1)"...formed within large ultramafic intrusive

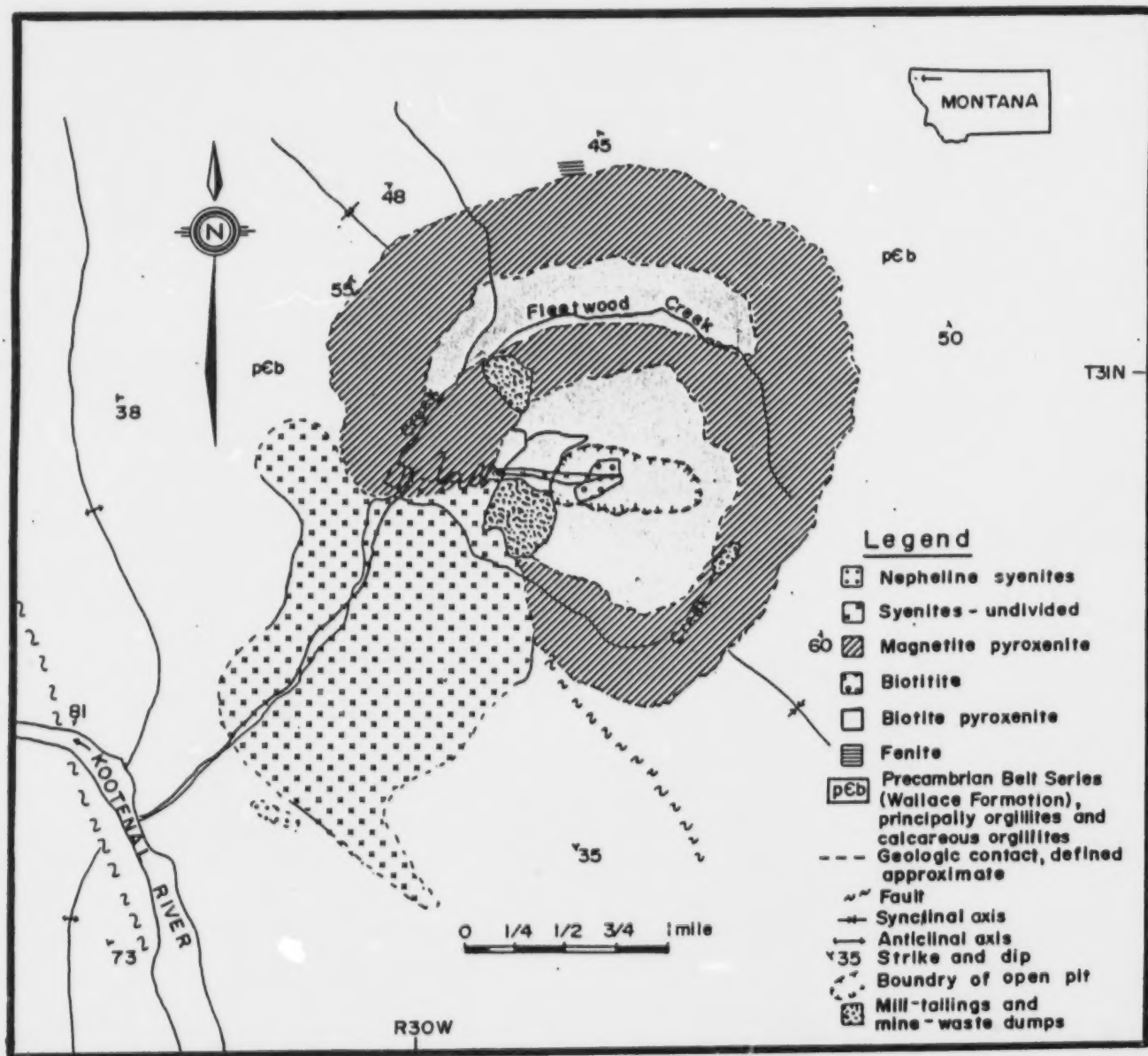


Figure 4, Geologic map of the Rainy Creek Complex near Libby, Montana (after Bush 1976).

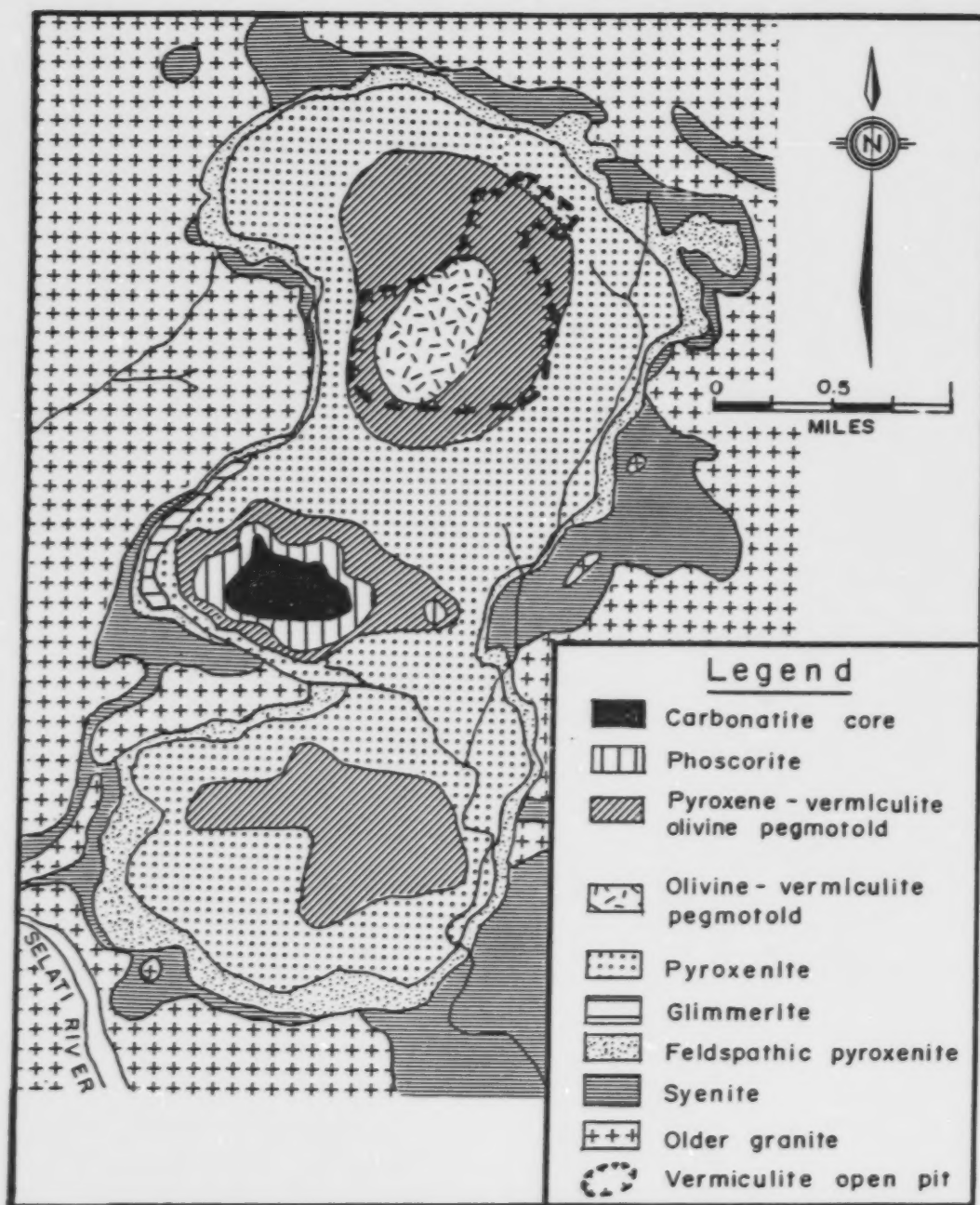


Figure 5, Simplified geological map of the Palabora Igneous complex showing the approximate location of the vermiculite open pit (after Harben and Bates 1984).

masses, such as pyroxenite plutons, cut by syenite or alkalic granite, and by carbonatitic rocks and pegmatites, (2) associated with ultramafic intrusive bodies, such as dunite and unzoned pyroxenite and peridotite, cut by pegmatite and syenitic or granitic intrusives, and (3) formed from ultramafic metamorphic rocks such as amphibole schist in contact with pyroxenite or peridotite and cut by pegmatite." Libby, Montana (USA) and Palabora, South Africa are examples of type 1, which produce approximately 93% of the world's vermiculite. Type 2 is typified by the Blue Ridge Mountain area of North Carolina, and type 3 by the Enoree district in South Carolina.

The largest deposit of vermiculite in the world occurs in the Rainy Creek Complex, near Libby, Montana, shown in Figure 4. The host rock is a zoned pyroxenite with a biotite core (biotitite) in a central biotite pyroxenite, ringed by magnetite pyroxenite. These intrude Precambrian Belt Series (Wallace Formation) metasediments (principally argillites and calcareous argillites) and is dissected by a younger mass of syenite and alkalic syenitic dykes. A small nepheline mass nearby and fenitized Belt Supergroup rocks suggest the presence of a carbonatite at depth (Bush 1976).

The Palabora deposit, the world's other major source of vermiculite occurs in the Palabora Carbonatite Complex (Figure 5). The complex contains three separate igneous cores which are surrounded by a feldspathic pyroxenite which merges inward to a true pyroxenite, to an apatite-bearing phlogopitic pyroxenite, and finally to a pegmatoidal pyroxenite-phlogopite/vermiculite-

apatite assemblage (Harben and Bates 1984). The mineralization which averages 22% vermiculite is restricted to depth of 40-50 metres where it changes to unaltered phlogopite mica (Clarke 1981).

PERTH STUDY AREA -- GENERAL GEOLOGY

Previous Mapping

H.G. Vennor (1870-1876) and R.W. Ellis (1905) worked in the general area of Frontenac, Leeds and Lanark Counties. The precambrian geology was examined by Dugas and Wilson (1961, 1:63,630 scale) and incorporated into compilation maps by Hewitt (1964, 1:126,720 scale) and Kingston et al, (1985, 1:125,000 scale). The Paleozoic geology was mapped by Williams and Wolf (1984, 1:50,000 scale). Hoadley (1960, 1:6,000 scale) and Guillet (1962) examined the vermiculite occurrences in the Perth Area.

General Geology

The rocks in the map area can be stratigraphically subdivided into three age groups: the oldest Grenville Supergroup Metasedimentary rocks are cut by Late Precambrian intrusive rocks, and are overlain by Paleozoic Sedimentary rocks.

Grenville Supergroup Metasedimentary Rocks

The Grenville Supergroup is represented within the map area by the sequence: marble (limestone), quartzite (sandstone), and aluminous quartzofeldspathic gneisses (shale). The metasediments have been isoclinally folded in a north-east direction, generally

coincident with the Grenville structural fabric, but locally the structure is more complex. There are no conspicuous faults, and only discontinuous jointing is present within the Precambrian terrain.

The metasedimentary succession has been subdivided into: 1. Calcareous metasediments (crystalline limestone, dolostone, and metamorphic pyroxenite), and 2. Clastic metasediments (quartzite, and quartzofeldspathic gneisses).

Calcareous Metasediments. Crystalline limestone and dolostone represent the oldest stratigraphic units in the area and principally outcrop in a band along the north shore of Pike Lake on the Westport Road. The marble is generally white to buff coloured, with a medium to coarse-grained, granular to massive texture. Phlogopite, diopside, serpentine and disseminated graphite are commonly found accessory minerals within the marble. In addition the presence of allietite (Miles and Springer 1988) and corrensite (DeKimpe and Miles 1987, 1988) has recently been reported. Wilson and Dugas (1961) observed "...inclusions of fragments of younger rocks, around which the limestone has molded itself as in a plastic flow." in several localities within this marble band. These features were also noted at several locations in the present study.

Pyroxenite occurs in two north-east trending bands. The southern band, in the vicinity of the Olympus pit, appears to be of metamorphic origin, produced from an "alteration of a dolomitic marble by the action of siliceous emanations from igneous

intrusions" (Wilson and Dugas 1961). It is a light green, medium to coarse-grained rock, with a competent to friable texture. Accessory minerals occurring in varying proportions include: tremolite, talc, serpentine, phlogopite, hydrobiotite, aliettite, calcite, dolomite (?), quartz and vermiculite. A more detailed examination of the pyroxenite in the vicinity of the Olympus pit will be presented later in the report. The northern band of pyroxenite may possibly be of igneous origin, and is crosscut by phlogopite dykes. These dykes were mined in the past as sources of phlogopite, as evidenced by the numerous trenches and pits (up to 7.6 m (25 ft.) deep) on concession 8, lots 16, 17, North Burgess Township. The phlogopite dykes are pyroxenite-hosted; phlogopite plates up to 0.45 metres in diameter were observed in several pits.

Vermiculitization of phlogopite has been observed in both bands, but only in the southern band does it appear to be developed in any significant quantity.

Clastic Metasediments. The quartzite unit includes a pure massive white unit, which may contain iron oxides, similar in appearance to vein quartz. A second unit, contains tremolite-actinolite, and sometimes talc, and is interbedded with thicker bands of quartzite. A third unit, contains interbedded quartz and brown crystalline marble, which may exhibit flow deformation. Small lenses of pyroxenite occur interbedded within the quartzite; they have been found to contain a minor amount of disseminated hydrobiotite, vermiculite and phlogopite.

Quartzofeldspathic paragneiss outcrops south of Pike Lake and on a few southern islands. It is also found as migmatitized remnants of rusty or graphitic paragneiss within granitic intrusives. Common accessory minerals within the paragneiss include biotite, garnet, hornblende, and graphite. Garnet-biotite paragneiss is the most common rock type of this unit. In the southern portion of the map area it has been intruded by syenite and diorite.

A hornblende-rich paragneiss occurs in a few small, isolated pockets within the more extensive biotite-rich paragneiss.

Late Precambrian Intrusive Rocks

Wilson and Dugas (1961) inferred that the intrusive masses were emplaced through "the processes of metasomatism and by doming of the adjacent sedimentary rock, particularly where the invaded rock is the most susceptible, as in the case of garnet gneiss." This has resulted in a gradual zonation from massive syenite in the centre of the plutonic body to a syenite gneiss, syenite-migmatite and finally unaltered garnet gneiss. This change was also observed by William and Dugas (1961) in the Perth Area and by Wynne-Edwards (1967) in the Westport Area to the south. Syenite-migmatite represents a transitional phase between rocks of igneous and sedimentary origin.

The syenite is variable in texture and grain size, but commonly contains microcline, plagioclase, biotite, and hornblende, with the accessory minerals sphene, magnetite-ilmenite, and apatite.

Diorite occurs as irregular patches within the syenite-migmatite in the south-eastern part of the map area associated with remnant rusty paragneiss.

Pegmatitic dykes cross-cutting the granitic rocks of the area consist essentially of microcline and quartz.

Wilson and Dugas (1961) believed that quartzite was transformed into granite, and garnet gneiss into syentite, through chemical readjustment during the granitizing process that formed the syenite-migmatite complex.

Paleozoic Rocks

The undulating Precambrian erosional surface was unconformably overlaid by a variable thickness of the Cambro-Ordovician Nepean Formation. The unit has been differentiated into two common types, based on the nature of the cementing material, a hard quartzite with secondary quartz overgrowth, and a more friable rock cemented by calcite (Williams and Wolf 1984).

The formation is flat to low lying, and composed of white to buff, medium-grained, quartz arenite. The grains are well-sorted and subround to round in shape, and are usually calcite cemented. Small rust spots are common, as are cross-bedding, cross-lamination and scour structures. Beds are generally of a medium thickness, ranging from very thin to massive (up to 2 metres) (Wynne-Edwards 1967). The irregularity of the Precambrian surface has resulted in the Nepean being of variable thickness.

In addition at the unconformity some indication of a post-Grenvillian pre-Nepean erosional event is locally recorded, which may have influenced vermiculite formation. Wilson and Dugas (1961) described a conglomerate on the western shore of Rideau Lake 8 km west of Stanleyville which appears to be of this age interval and differs from Nepean conglomerate. Twenty kilometres to the northwest, the Playfair (Dalhousie) iron mine contains pyrite pervasively oxidized to hematite (Rose 1958), an effect which could also be attributed to deep weathering.

VERMICULITE OCCURRENCES IN THE PERTH AREA

The Perth Area occurrences are widely distributed throughout the Stanleyville-Pike Lake area. Significant occurrences are the P. Farrell property and Olympus Mines Ltd. property. Numerous other small occurrences which occur within the map area in the form of veins and disseminations within the marble are recorded on Map 1, in the back pocket. Since the only other significant occurrence of vermiculite reported in southeastern Ontario is the Goshawk Mines Ltd. property in Cavendish Township a brief description of this property is presented in Appendix B.

P. Farrel Property (Norden Vermiculite Ltd.)

Location and Access. The property is situated on lot 14 and north half of lots 15 and 16, concession 9, North Burgess Township, Lanark County, approximately 11 km southwest of Perth on County Road 10.

Previous Work. North Bay Mica Co. Ltd. trenched and diamond drilled the property in 1951-1952. Northern Vermiculite Ltd. (E.A. Vacheresse) optioned the property in 1956 and established a pilot exfoliating plant in Perth which in 1957 was replaced by a small commercial plant at Glen Tay. Mr. Vacheresse (in Guillet 1962) reported that 15,000, 4 cubic foot bags were produced from these two small exfoliating plants, before operations ceased. In 1958, Rochester and Pittsburgh Coal Co. optioned the property and conducted 610 m (2,000 ft.) of diamond drilling. E.A. Vacheresse packsack drilled an additional 13 holes in 1960 and in 1961 the company was renamed Norden Vermiculite Ltd. (Guillet 1962).

Geology. The detailed geology (Figure 6) of the property could not be observed in the field due to caving or infilling of trenches, flooding of the pit (45 X 12 m), and recent road construction which obliterated a considerable number of the trenches in the area.

Guillet (1962) describes the main zone as "...a steeply plunging pod of coarse grained phlogopite-diopsidic gneiss enclosed by a moderately silicated marble. The zone is 61 X 21 m (200 X 70 ft.) elongated in a northeast-southwest direction and plunges 75 degrees to the east." The degree of vermicultization is generally low and occurs as disseminations within the marble band. Small lenses of biotite schist occur elsewhere on the property containing a high degree of vermiculitization. Several small (up to 1.5 m) syenitic dykes were reported by Guillet (1962) to transect both the vermiculitized zone and wall rocks, generally striking north-east and dipping easterly.

**VERMICULITE PROPERTY
OF
NORDEN VERMICULITE LIMITED**
NORTH BURGESS TOWNSHIP, LANARK COUNTY
LOT 14, CONCESSION IX

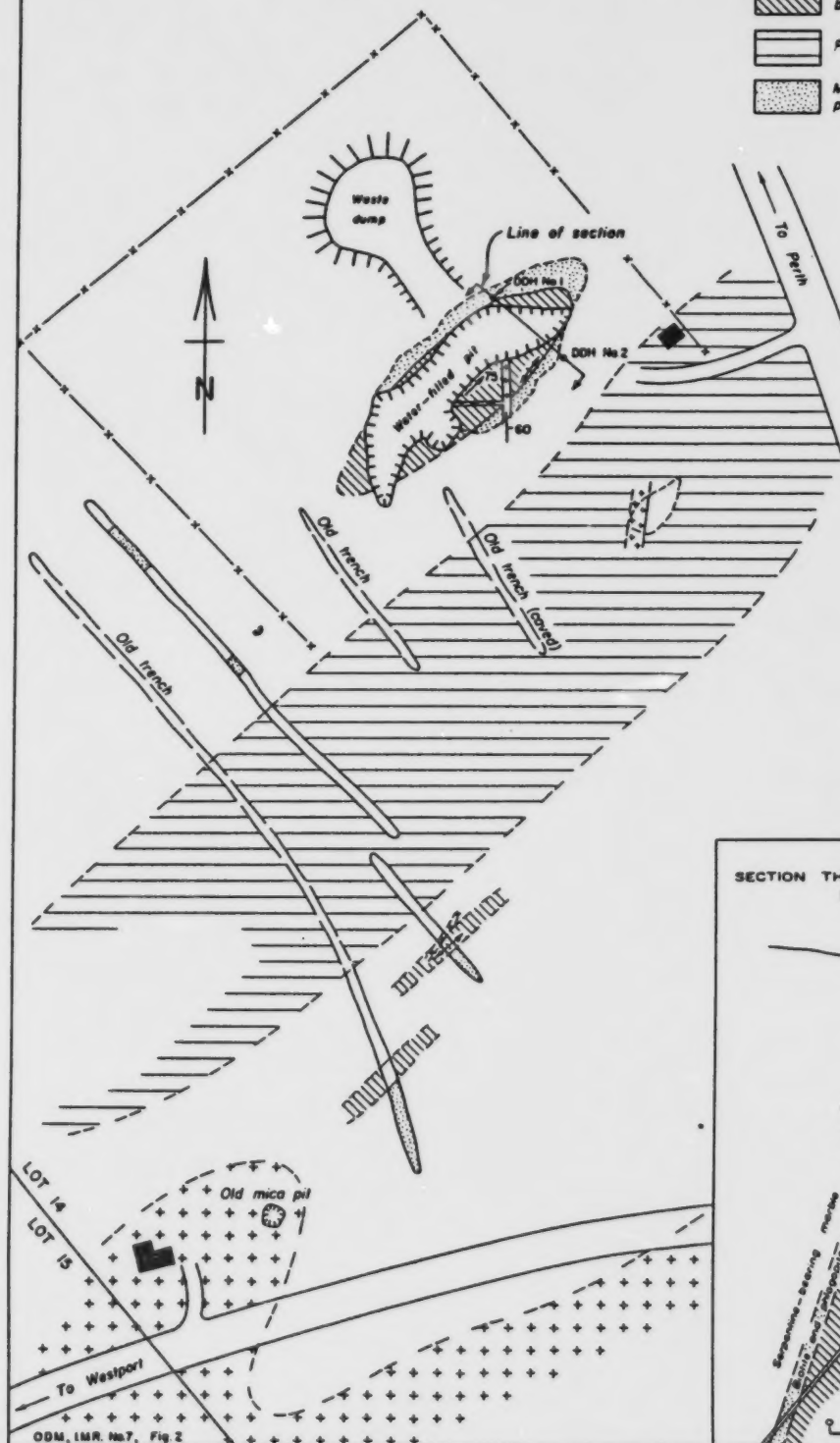
LEGEND

-  Pink leucosyenite gneiss and pegmatite.
-  Serpentinized phlogopite-diopside gneiss or biotite schist. More or less vermiculitized.
-  Feldspathic paragneiss, quartzite, migmatite.
-  Marble, more or less speckled with biotite, phlogopite, and serpentinized diopside.

Scale of Feet
30 0 30 100

SYMBOLS

-  Strike of vertical foliation
-  Trend and plunge of lineation
-  Rock contact defined, approximate, assumed
-  Open cut, pit
-  Rock outcrop
-  Trench
-  Fence



**SECTION THROUGH MAIN VERMICULITE ZONE
LOOKING SOUTHWEST**

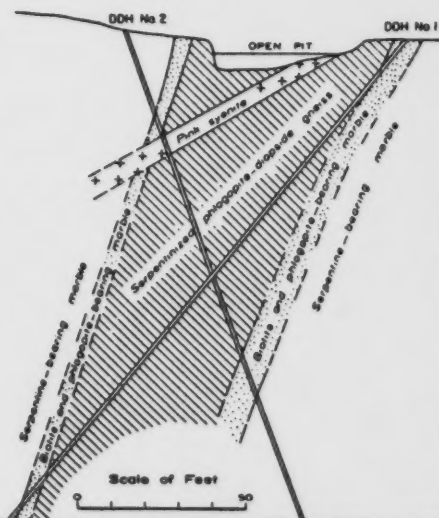


Figure 6, Geology of the P. Farrel (Norden) property
(from Guillet 1962)

Deep weathering, a common feature associated with vermiculite at the Olympus Mines Ltd. property, is not an apparent feature of this occurrence.

Olympus Mines Ltd. Property

Location and Access The property is located on the north half of lots 17 and 18, concession 8, North Burgess Township, (100 acres are patented in lot 17), approximately 0.8 km southwest of Stanleyville and approximately 13 km. by road from Perth, Ontario. The Canadian Pacific Railway's main line passes through Perth.

History of Property. In 1950, G.C. Bruce of the Industrial Minerals Branch, Ottawa discovered the deposit. Siscoe Vermiculite Mines Ltd., a new subsidiary of Siscoe Gold Mines Ltd., optioned the property a few days later and engaged in a program of auger drilling, test pitting, and trenching. In 1959, the property was sold to Olympus Mines Ltd. and the company began developing the property in June 1960 by drilling 45 auger holes, and 2 diamond drill holes, and by developing the open pit. By 1963 the stockpile reached an estimated 136,000 tonne (165,000 tons) of vermiculite-bearing material and produced from a 305 m (1,000 ft.) X 91 m (300 ft.) X 9 m (30 ft.) pits. A processing plant was constructed by 1965 and some material was processed, but the operation proved uneconomic. In 1968, a consortium in Ottawa, Worldwide Energy Company Ltd., optioned the ground and retained G.H.D. Consultants of Toronto to evaluate the property in 1969. They drilled 4 holes, totalling 578 m (1,896 ft.) and

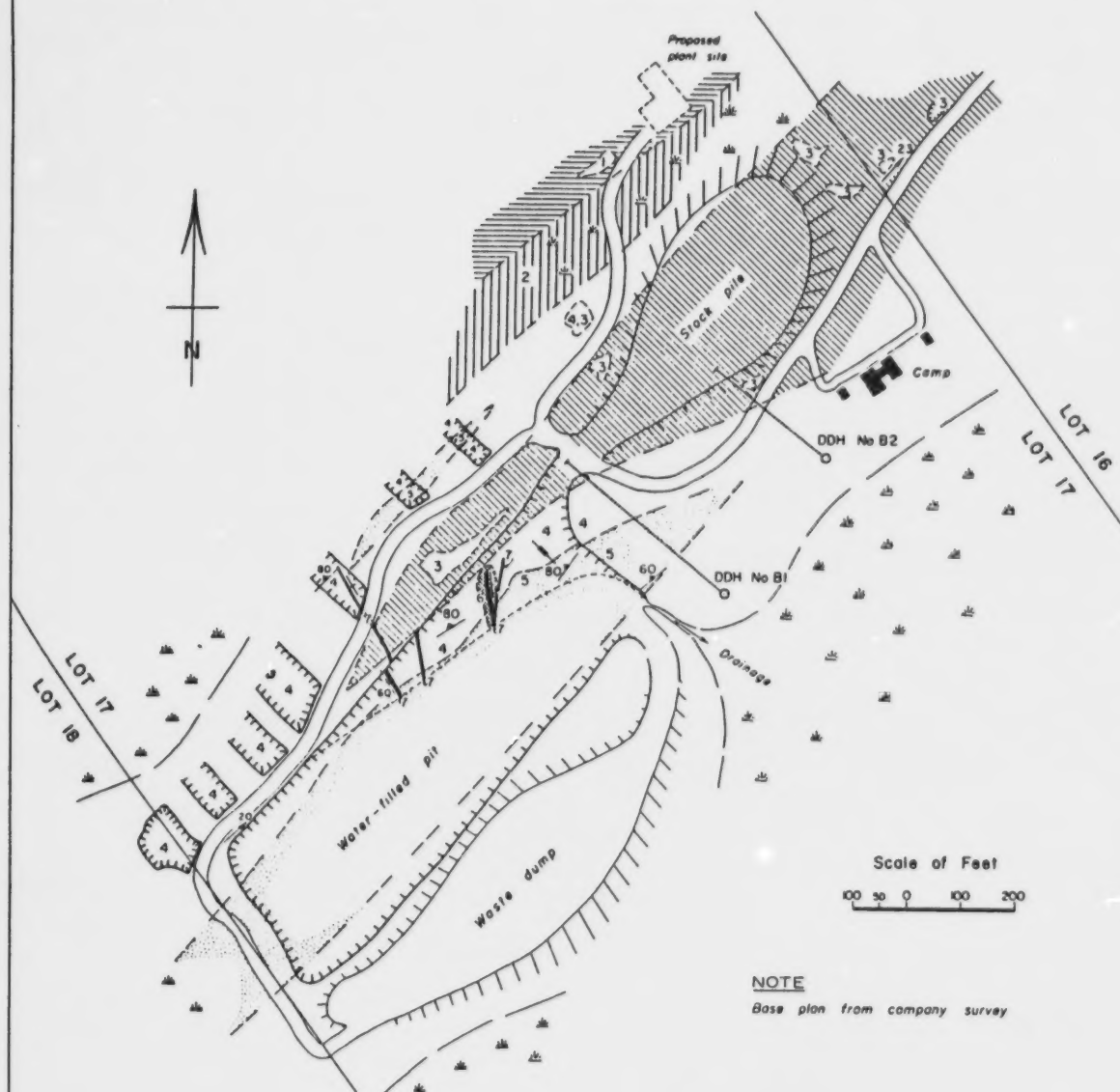
trenched approximately 610 m (2,000 ft.) (appendix C). A 450 kg (1,000 lb.) and a 4,500 kg (10,000 lb.) bulk sample were taken from the east face of the pit. The 450 kg (1,000 lb.) sample was sent to Montreal for analysis and the 4,500 kg (10,000 lb.) sample retained for a batch test in the existing plant. Results of these tests were not available. Drill results concluded that this deposit could support a 270 tonnes (300 ton)/day operation for 10 years, with the mill-feed grading 20% vermiculite (Cunningham 1969; Guillet 1962). The property is currently owned by Cye Ross of Canalex Resources Ltd.

Geology. The geology in the immediate vicinity of the property (Figure 7) consists of Grenville Series rocks; paragneisses, quartzite, crystalline limestone and dolostone and metamorphic pyroxenite. The vermiculite occurs in a thinly banded, pale blue-green, serpentized metamorphic pyroxenite which is flanked on both sides by a hornblende or biotite paragneiss that changes to quartzite northwest of the pits and disappears into swampy ground to the southeast.

The main mineralized zone strikes 052° and dips 80° northwest and can be observed along the northeastern face of the pit. Diamond drilling by G.H.D. Consultants in 1969, established an average width for the zone of 40 m (130 feet) varying between 24 m (80 feet) and 45 m (150 feet), and a minimum length of 425 m (1400 feet). Trenching showed that in the centre of pit the vermiculitized zone is only 24 m (80 feet) wide (Cunningham 1969; appendix B). The mineralized zones consist of thin bands of pale brown hydrobiotite/vermiculite-rich rock <2.5 cm wide,

VERMICULITE PROPERTY OF OLYMPUS MINES LIMITED

NORTH BURGESS TOWNSHIP, LANARK COUNTY
LOT 17, CONCESSION VIII



NOTE
Base plan from company survey

LEGEND

- | | |
|--|--|
| | Diorite, more or less serpentinized |
| | Tremolite metamorphic pyroxenite |
| | Thinly banded vermiculite metamorphic pyroxenite |
| | Vermiculite-poor hornblende metamorphic pyroxenite |
| | Hard unaltered metamorphic pyroxenite |
| | Dark paragneiss |
| | Quartzite |

SYMBOLS

- | | |
|--|--|
| | Strike and dip of gneissosity |
| | Trend and plunge of lineation |
| | Attitude of dike. Inclined dip; vertical dip |
| | Vertical jointing |
| | Rock contact defined, approximate, assumed |
| | Boundary of rock outcrop |
| | Pit or trench |
| | Stockpile or waste dump |

BBM, IMR No 7, Fig 1

Figure 7, Geology of the Olympus Mines Ltd. property
(from Guillet 1962)

alternating with almost barren, altered light green diopsidic rock. The hydrobiotite/vermiculite flakes are usually <0.3 cm in diameter, and may vary in colour through pale brown, amber, olive-grey, and silvery. In addition to the banded and disseminated mineralization found within the main zone, there are vertical veins of coarser-grained phlogopite/hydrobiotite up to 8 cm across. This feature is evident on both the northeastern and northwestern faces of the pit but is more prevalent on the northwestern face. Guillet (1962) reported that three additional vermiculite-bearing zones of limited extent occur on the property.

The hanging wall grades into relatively hard, competent, cream-grey, less intensely altered pyroxenite and the contact between it and the main zone is irregular due to interbanding of the vermiculitized pyroxenite with barren pyroxenite. This is evident on the surface and in samples obtained from the current drill programme. Northwards further from the presumed source of the hydrothermal solutions the dominantly diopsidic pyroxenite becomes enriched in tremolite, which occurs as brown, prismatic, vitreous grains. The pyroxenite is interbanded conformably with quartzite and actinolite-tremolite-talc schists.

The main zone is dissected by undulating, horizontal and occasional vertical fractures and intruded by dioritic dikes (Plate 1). The fractures are generally <10 cm thick and filled with grey-blue, massive to fibrous talc. Fibrous talc may pseudomorph serpentine, thus accounting for its increased hardness (Wolfson, 1980).



Plate 1, Altered dioritic dyke (far right) intruding highly friable saprolitic pyroxenite (NW pit face).

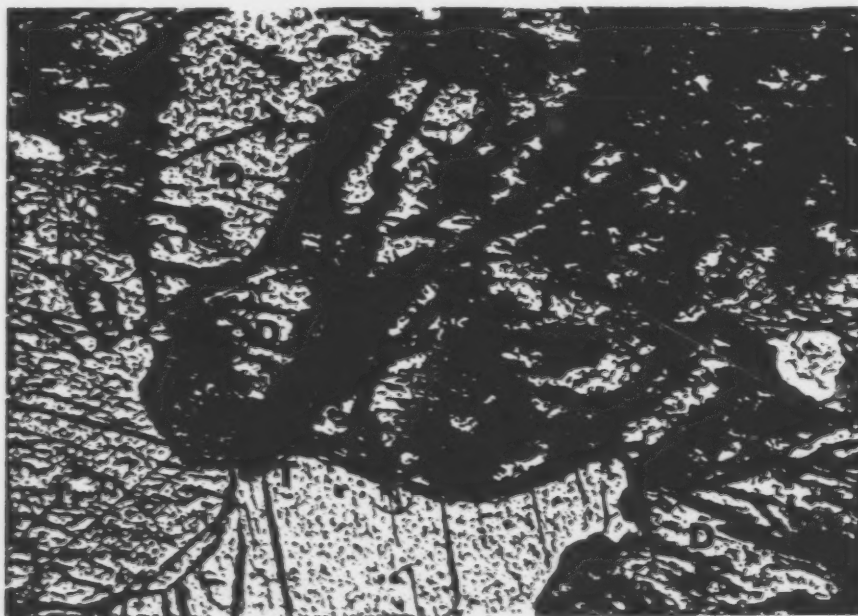


Plate 2, Intergrown diopside and tremolite, with talc alteration its distribution it appears to be the result of weathering (Tr-tremolite, D-diopside, T-talc-oxide alteration).

Near the present surface, the host pyroxenite is highly friable, resembling sand in texture and appearance (Plate 1). This grey saprolitic zone is composed of varying proportions of hydrobiotite, vermiculite, allietite, corrensite, tremolite, talc, serpentine, and phlogopite, with minor diopside, chlorite iron oxides, dolomite, calcite, and pyrite (N. Miles, Mineralogist, Agriculture Canada, Ottawa, personal communication, 1989). The greenish-white diopside is medium grained, hypidioblastic to xenoblastic in habit, and has a woody appearance. However, little of the pyroxene (diopside) remains preserved due to the extreme nature of the alteration. Thin section examination indicates an intergrowth with amber, idioblastic to hypidioblastic tremolite. A brown alteration observed along fractures and cleavages within the diopside has been identified by electron microprobe analysis as talc stained with iron oxides (Wolfson 1980). This feature is evident in Plate 2.

Near the top of the section, there are several indications of a later episode of alteration. For example, the top 9-12 metres is looser and more weathered than the rocks below. This can be observed in (a) drillcore, (b) the pit face where diorite dikes (Plate 2,3) in the main zone have been partly serpentinized steatized and chloritized and weather an orangish colour staining the pit face, (c) thin sections, where alteration products (e.g. talc) are observed to be dusted or stained with iron oxides and (d) the presense of this grey saprolitic zone containing grey-green clay-sized allietite, coating coarser, crumbly

phlogopite-talc grains (Miles and Springer 1989). This alteration decreases from the present surface downwards and from its distribution, it appears to be the result of weathering. Wilson and Dugas (1961) and Rose (1958) presented incidental evidence of erosion and weathering before the Paleozoic, and it is possible that today's surface is in part the re-excavated Precambrian unconformity underlain by material generated during pre-Paleozoic weathering. This may be important in understanding the distribution of the vermiculite because a paleoweathering surface would closely define the stratigraphic position of the vermiculite. Examples from other vermiculite deposits such as those at Libby, Montana (Boettcher 1966), and South Carolina (Libby 1975) suggest that high-grade metamorphism produces biotite or phlogopite from which vermiculite is subsequently formed by meteoric waters under weathering conditions.

SEPARATION AND BENEFICIATION STUDIES

Previous Testing

Wilson (1957) of the Mines Branch, performed tests on vermiculite samples, submitted by Northern Vermiculite Ltd. (P. Farrell Property), to obtain data on differential reduction using three different types of crushers. A usable 28 mesh product could not be produced, but partial concentration was obtained by electrostatic separation and by air tabling.

However, the majority of testing was performed on samples obtained from the Olympus Mines Ltd. property (Wilson 1961, 1969; Wyman 1964). Wilson (1961) tested 30 samples of split diamond drill core, two samples from the surface of the pit, one from the

stockpile, and an auger sample from the floor of the pit. These samples were evaluated for weight percentage vermiculite, percent insulation grade (wt.%), bulk density of exfoliated product, and effect of firing temperature on exfoliation. Results indicated an average of 25% vermiculite (7.2-41.7%) from samples taken from the pit floor, of which over 65% was in the minus 14 to plus 48 mesh size range. An average of approximately 15 percent of product met ASTM size specifications for insulation, while the bulk was suitable for plaster aggregate. The exfoliated products taken from below the level of the pit, however, had unit weights much in excess of ASTM specifications for use as aggregate in gypsum plaster. Exfoliated products obtained from the stockpile were within ASTM specifications, close to its upper limit. Varying the firing temperature between 1,700°C and 2,000°C on arbitrarily selected samples of minus 28 plus 48 mesh material had no appreciable effect on the degree of exfoliation.

Wilson (1961) experimented with several beneficiation methods and concluded that neither electrostatic nor magnetic separation were effective in concentrating the vermiculite. Only partial concentration was obtained with heavy liquid separation (s.g. 2.8).

Wyman (1964) conducted further testing on two 1800 kg (4,000 lb) samples to determine a suitable beneficiation method. Separation and beneficiation techniques employed included self-grinding, wet tabling, Wilfley tabling, jigging, and a Humphreys Spirial, in conjunction with a diagonal deck shaking table, and dry testing

using an air table and differential rollers crushing. He concluded that wet tabling methods were unlikely to succeed since even short exposure to water was sufficient to induce breakdown of the vermiculite. Wet jigging a +8 mesh feed produced only a small quantity of high grade vermiculite. Using differential rollers on a dry feed and concentrating by air tabling, a product containing 75% vermiculite with a 66% recovery could be obtained and this could be upgraded to 86% with a 30% recovery (Wyman 1964).

Wilson (1969) analysed three samples of split core submitted by G.H.D. Consultants Ltd. for vermiculite content, vermiculite flake size and bulk density of the exfoliated vermiculite recovered. The samples contained 15-19% recoverable vermiculite; with between 68 and 77 percent of the vermiculite in the minus 8 plus 48 mesh size. Although the minus 8 plus 48 mesh fraction did not meet ASTM bulk density specifications for concrete aggregates, Wilson (1969) suggested that a reduction in bulk density might be achieved through more rapid heating during the exfoliation process.

CURRENT TEST WORK

Sample Techniques

Two samples were taken from the Olympus Mines Ltd. Property during the present investigation in order to conduct preliminary beneficiation testing; a 160 kg. chip sample and a 35 kg drill core sample.

The chip sample (grab sample), was taken across a 15 m section of the cleaned northeastern face of the pit, rich in hydrobiotite/vermiculite. Core samples of a deeper section of the mineralized zone were obtained from an inclined drill hole striking 140° and dipping 57° , (hole ST-1, appendix C) that is parallel to the northeastern pit face. The hole was drilled to a vertical depth of 43.6 m and is 52.1 m in length. From the split core, half was shipped to the Ministry of Northern Development and Mines core storage facility in Tweed and half (12.2-43.6m) was sent to CANMET for testing purposes.

Recovery of the first 12.2 m of core was in the form of sludge, due to the highly weathered nature of the rock. Various techniques were employed, such as: a rotating core barrel, varying the drill speed and water flow, and changing the core size. None of these methods resulted in an increased core recovery.

Separation and Beneficiation

A. Sample Preparation

The chip sample was screened into four size fractions $-2.0 + 0.6$ mm, $-0.6 + 0.3$ mm, $-0.3 + 0.15$ mm, -0.15 mm, with the plus 2.0 mm fraction crushed by a dual roll crusher and the -0.15 mm fraction discarded. The core sample was divided into two samples, drill core Sample 1 (12.3 to 27.7 m) and drill core Sample 2 (27.7 to 43.1 m); each sample was crushed independantly using a dual roll crusher in four consecutive stages with intermediate sizing at 2 mm and similarly screened. Crushing became more difficult with increasing depth, resulting in more fines being formed.

B. Dry Beneficiation

(i) Magnetic Separation. The individual size fractions of each of the three samples were processed in a Carpco magnetic separator at different field intensities. However, no mineral concentrations were apparent at either low or high coil current.

(ii) Electrostatic Separation. Again results were poor; at low voltage (5,000 volts) 'skin' vermiculite was concentrated but the vermiculite books remained in the reject portion, and at higher voltages (>10,000 volts) recovery increased but remained unconcentrated.

(iii) Air Tabling. Gravimetric separation was not successful because of the small difference in specific gravity between the minerals involved and the fact that the vermiculite books have an aspect ratio similar to that of associated tremolite and other gangue minerals.

A disc pulverizer was used in an attempt to enhance the shape difference between the vermiculite and other gangue constituents. Regardless of the gap distance delamination occurred, resulting in the production of too much skin vermiculite.

C. Wet Beneficiation

(i) Flotation. The minus $-0.2 + 0.15$ mm fraction of the samples were floated using a Denver laboratory flotation cell, to examine the possibility of upgrading the vermiculite content without further optimization (Table 12). It is interesting to note that for of the weathered sample, vermiculite floated best using an

alkaline pulp with tertiary amine as the vermiculite collector, while vermiculite from drill core samples floated only under acidic conditions.

Attrition of the cell propeller resulted in the coarse vermiculite delaminating and excessive slimes being produced. The -2.0 + .6 mm fraction was difficult to float in a conventional flotation cell. Lamothe and Wang (1986) suggested that these problems may be minimized by using a column flotation cell instead of a mechanical type.

Table 12 Flotation test results

Sample description	pH ¹	Reagent	Description
-0.3, +0.15 mm (chip sample)	10	amine ²	vermiculite floats with some talc and tremolite 60% vermiculite in float product
-0.3, +0.15 mm (chip sample)	4		poor flotation of verm.
-0.3, +0.15 mm (chip sample)	4	oleic acid ³ & frother	flotation of talc with some vermiculite
-0.3, +0.15 mm (core sample)	10	amine ²	no flotation
	4	amine ²	vermiculite floats with impurities 70% vermiculite in float product

1-pH regulated with H₂SO₄ and Na(OH)

2-tertiary amine, Ethomeen T/15

3-Dow D250

(ii) Hydrogen Peroxide Tests. Samples from the $-0.6 + 0.15$ fraction of the chip sample were treated in a water solution containing various concentrations of hydrogen peroxide (H_2O_2). After a few minutes, bubbles selectively form on the surface of the vermiculite and when enough bubbles form, the vermiculite rises to the surface of the cell and can be removed. The most promising results were obtained during a quiet flotation using a water solution containing 10% volume of H_2O_2 and tertiary amine as a collector.

Lamothe and Wang (1986) in one test skimmed the floated material off after 20 minutes, the float consisted essentially of exfoliated vermiculite (95-98%) with little 'skin' vermiculite. In a second test, the floated material was skimmed off every 2 minutes, the float consisted of 60% or more unexfoliated vermiculite.

D. Pre-Exfoliation Method

Samples (chip sample, drill core sample 1, drill core sample 2) were separately crushed and screened into four fractions, $-20 + 0.6$ mm, $-0.6 + 0.3$ mm, $-0.3 + 0.15$ mm and -0.15 mm, the latter being discarded and the $+2$ mm fraction circulated.

Each fraction was then thermally treated in a laboratory tube furnace at $2,000^{\circ}F$ to exfoliate the vermiculite. Residence time increased with the fineness of the feed. Heat treatment was not optimized, emphasis was on upgrading and recovery of vermiculite by mechanical means (Lamothe and Wang 1986). The exfoliated

fraction was separated using a 300 X 500 mm deck Denver air table.

By definition a product was considered a concentrate when the vermiculite content was more than 90-95% by volume, a middling (40-90%) and a reject (lower than 30-40%). Under production conditions the middlings would be returned to the feed point for recycling.

Preliminary testing indicated that the overall concentrate recovered from the chip sample totaled 31.1% by weight (61.6% total volume exfoliated), middling portion 11.3% by weight (9.8% total volume) and the reject portion 57.6% by weight (28.6% total volume). Practically all the vermiculite (82% by volume) reported in the concentrate; with recovery increasing to 93.4% if the middlings were recirculated. Drill core sample 1 contained 21.9% total weight (51.7% total volume exfoliated) concentrate, representing a 72.9% by volume recovery of all vermiculite contained in the feed and drill core sample 2, 20.6% total weight (46.9% total volume) with a recovery of 81.5% by volume. If the middling were to be recirculated and recovered, recovery would increase to 92.5% by volume (Lamothe and Wang 1986).

Tests for Asbestiform Minerals

A problem of considerable importance to environmentalists and government agencies is the presence of asbestiform fibres in dust from vermiculite operations. E.J. Chatfield of Chatfield Technical Company tested vermiculite from the Olympus at the Ontario Research Foundation, Mississauga (Chatfield 1985).

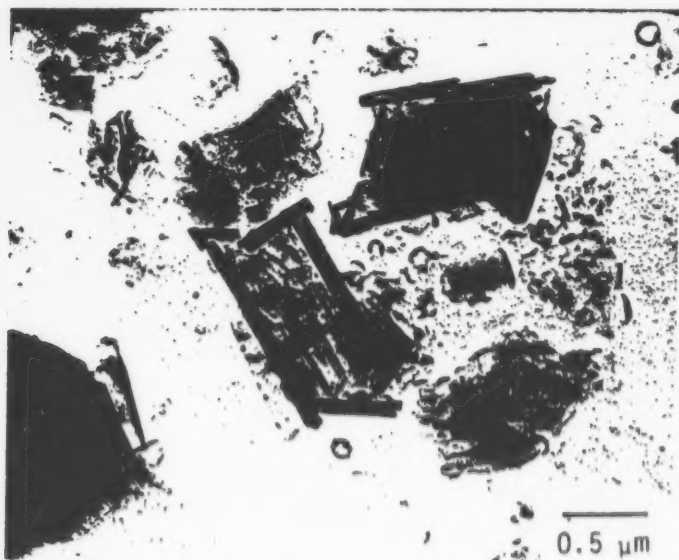


Plate 3, Flake edges curl into scroll-like tubes

Chatfield (1985) found that the vermiculite books show gradational changes of composition from the centre to the flake margins. Near the centre of each flake compositions approximate biotite and phlogopite but towards the edges of the flakes there is a progressive loss of potassium and aluminum so that the composition of chrysotile is approached, simultaneously the flake edges curl into scroll-like tubes; this phenomenon is illustrated in Plate 3.

The ore contains a minute fraction of these scrolls (12.1×10^6 fibres/gram ore, equivalent to a mass concentration of 0.11 ppm) classified as chrysotile. X-ray diffraction confirmed the presence of a small quantity of chrysotile (N. Miles, Mineralogist, Agriculture Canada, Ottawa, personal communication, 1989). In length the scrolls which average 0.5 to 0.73 μm are well below the 5.0 μm size that is of concern as dust hazard. There is also a very low concentration of amphibole fibres, 1.32×10^6 fibres/gram, equivalent to a mass concentration of 150 ppm.

Overall the low concentrations present and the shaft length of the fibres produced means that the dust from this deposit is unlikely to present any health concerns.

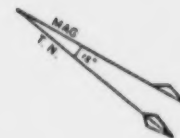
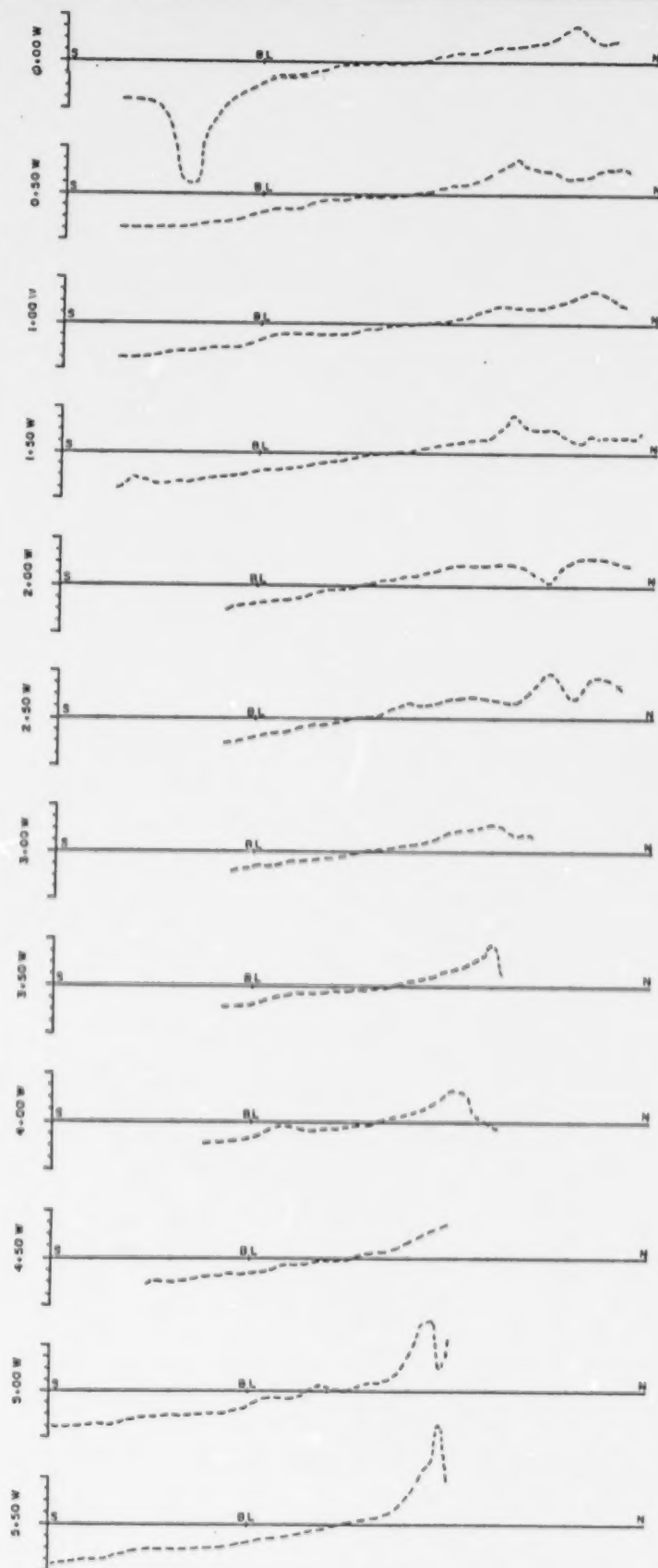
GEOPHYSICAL SURVEY

A ground magnetometer survey was completed during the summer of 1985 on part of the Olympus Mines Ltd. property by the Ministry of Northern Development and Mines Resident Geologist office in Tweed.

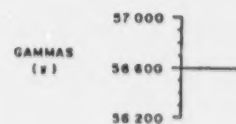
The main objective of the survey was to determine the possibility of tracing vermiculite pods and lenses associated with stringers and dykelets using geophysical techniques, and secondly, to determine the buried contacts between the different rock lithologies which might otherwise have to be determined only by extrapolation from outcrop areas.

The survey was conducted using a Geometrics '826' proton precession magnetometer (accurate to 1 gamma). Approximately 6.1 km of line was tranversed; line spacing was 50 m, with stations at 10 m intervals.

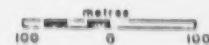
The data obtained was smoothed using a five point weighted running average to eliminate erratic readings. The results were plotted on a series of line profiles and a contour map (Figures 8 and 9 respectively). The survey was inconclusive, a large swamp east of the Olympus pit hides the expected source of the dykelets and stringers. Insufficient contrast between the magnetic susceptibilities of the different lithologies north of the pit resulted in minimal success in delineating buried contacts. The contour map partially illustrates the contact between the quartzite (interbedded with crystalline limestone) and the feldspathic paragneisses in the northeast corner of the map. The high readings in the northwest corner of the map area are due to overhead hydro lines, and the low in the southeast corner due to a metal mill building. There is an apparent gradual increase to the north, observed in the profiles and contour map (Figure 8 and 9 respectively). Rather than an increase northwards, the normal magnetic field appears to be depressed



LEGEND



SCALE



STANLEYVILLE
VERMICULITE
PROJECT

JUNE 1985

Figure 8, Ground magnetometer line profiles

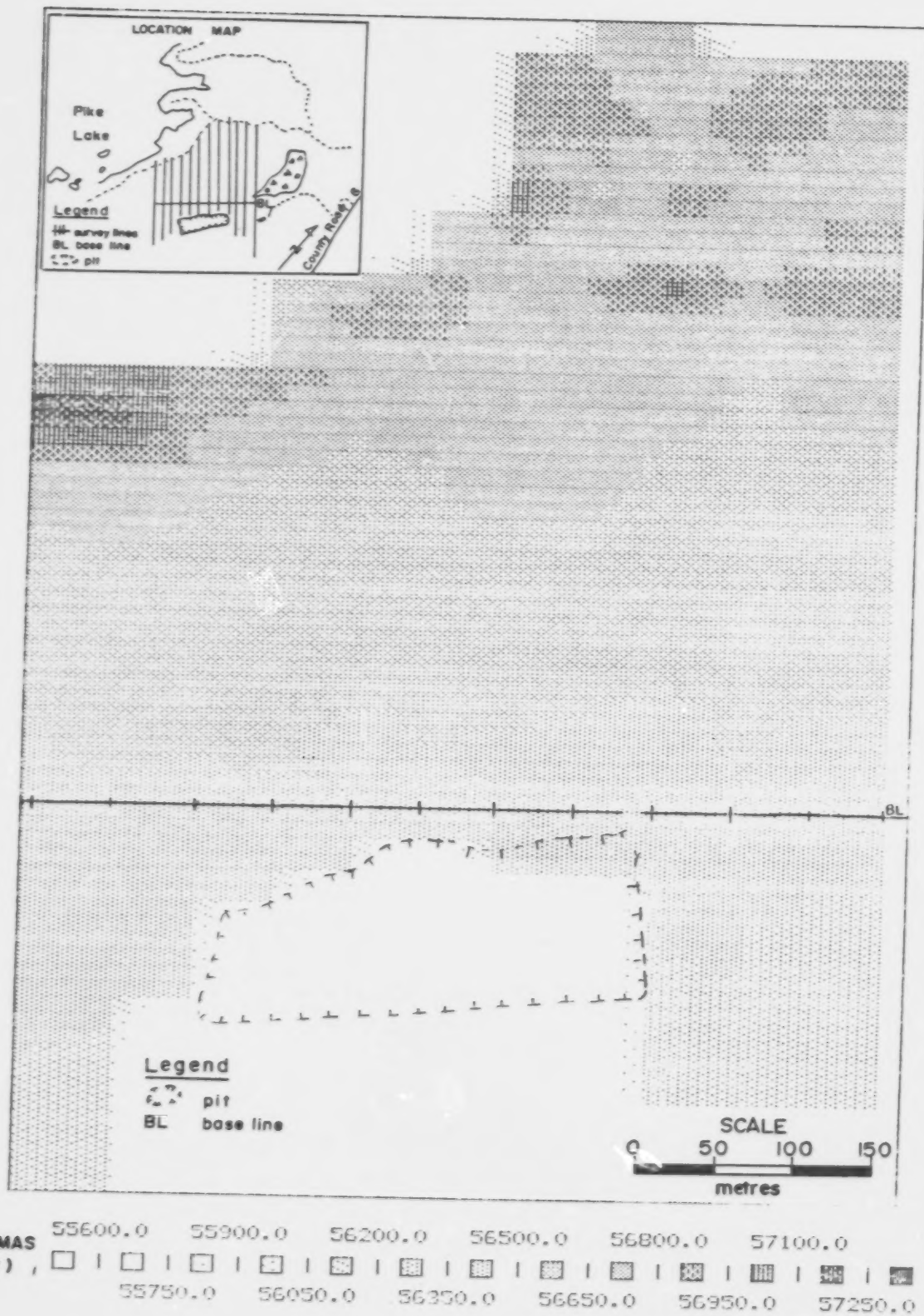


Figure 9, Contour map of ground magnetometer survey.

(lower than normal) towards the pit. This phenomenon may be due to the rock having a low magnetic susceptibility. Two small anomalies exist in the centre region of the map.

Conclusions

- (1) Shallow vermiculite development occurs at several localities near Perth, Ontario. An extensive zone of hydrobiotite/vermiculite mineralization occurs within a highly altered pyroxenite on the Olympus Mines Ltd. property. Previous drilling established an average width of 40 m, and length of 425 m for the mineralized zone. In the present study, mineralization was confirmed to a depth of 44 m.
- (2) The pyroxenite on the Olympus Mines Ltd. property is hydrothermal in origin, probably formed by silicification of the original dolomitic-rich marble. The mineralization on the Olympus property consists predominantly of hydrobiotite rather than vermiculite. The presence of allietite and corrensite indicates a high degree of alteration. This alteration may be due to hydrothermal or meteoric processes or a combination of both, however at present the origin remains uncertain.
- (3) Subsequent supergene alteration (weathering), both pre-Paleozoic and post-glacial may also have altered the upper parts of the orebody.
- (4) The ground magnetometer survey was not useful in delineating

the vermiculitized zones associated with the syenitic and dioritic intrusions.

- (5) Beneficiation tests show that crushing and screening gives good separation of raw hydrobiotite/vermiculite, particularly of the near surface ore. The ore varies with depth in its processing behaviour. Flotation with hydrogen peroxide and tertiary amine as the collector, under quiet conditions is also a successful separation technique for the raw hydrobiotite/vermiculite. A concentrate was obtained using the pre-exfoliation method with >90% recovery; however this method does not appear to be a viable alternative. Since energy requirements would be substantially higher than operations currently in production, (typically 1.5 million ETU/t of concentrate) due to the added expense of heating waste material. However the expense may be minimized if heat recovery methods were employed.
- (6) Small amounts of fibrous minerals are contained in the ore. The low concentration of fibres and their short length do not appear to constitute a health concern.
- (7) A Canadian market exists for vermiculite concentrates of approximately 24,500 to 29,000 tonnes/year plus 7,300 tonnes/year of expanded vermiculite for a Ontario (Perth) producer, because the location is favourable. However, problems with the contamination of asbestiform minerals within currently producing deposits could significantly increase market opportunities.

- (8) An increase in the U.S. demand for crude vermiculite of 2% per year is expected up to 1990. Canadian growth may be slightly lower.

- (9) An important consideration to the continued development of vermiculite resources involves the continued research and development of new technology such as improved beneficiation methods and new applications.

REFERENCES

- Anonymous
 1970: Vermiculite: A Market in Transition; Industrial Minerals, Number 38, p. 9-13.
 1977: Vermiculite increased capacity encourages optimism -- but construction still the key to demand; Industrial Minerals, Number 125, p.17-31.
 1983: Prices; Industrial Minerals, Number 255, p.83.
- Archibald C.W.,
 1976: Qualifying report on Cavendish Township property; Unpublished company report (June), Goshawk Mines Ltd., Canada, 14p.
 1977a: Progress and preliminary tonnage report for the directors of Goshawk Mines Ltd., Cavendish Township property; Unpublished company report (February), Goshawk Mines Ltd., Canada, 12p.
- Archibald, J.C.
 1977b: Summary report Cavendish Township, Ontario, vermiculite property; Unpublished company report (October), Goshawk Mines Ltd., Canada, 20p.
- Ballard, G.H., and Rideal, G.R.
 1983: Flexible inorganic films and coatings; Journal of Materials Science 18, p. 545-561.
- Barshad, I.
 1948: Vermiculite and its relation to biotite as revealed by base exchange reactions, X-ray analyses, differential thermal curves, and water content; The American Mineralogist, Volume 33, Number 11, 12, p.655-678.
- Beauregard, J.
 1982: The vermiculite industry in North America with an overview of markets in the E.E.C. and Japan -- A Market Study; Unpublished company report, Canalex Resources Ltd., Canada, 40p.
- Boettcher, A.L.
 1966: The Rainy Creek Igneous Complex near Libby, Montana; Ph.D. Thesis, Pennsylvania State University, 70p.
- Bright, E.G.
 1981: Precambrian geology of Cavendish Township (southern part), Peterborough County, southern Ontario; Ontario Geological Survey Preliminary map P.2421, Geological Series, scale 1:15 840 or 1 inch to 1/4 mile. Geology 1975, 1976, 1977.

- Bush, A.L.
1976: Vermiculite in the United States; Eleventh Industrial Mines Forum, Montana, September, 1976, Special Publication 74, United States Bureau of Mines, p. 145-155.
- Canadian Mineral Yearbooks 1970-1988 Review and Outlook edited by G.E. Thompson and G. Cathcart, Energy Mines and Energy Mines and Resources Canada.
- Chatfield, E.J.
1985: Examination of vermiculite from the Stanleyville, Ontario deposit for the presence of asbestos minerals, Ontario Research Foundation Report 3854030, 28p.
- Clark, N.C.
1982: The European vermiculite market -- The view from Mandoval; Industrial Minerals , Number 179, p.50-52.
- Clarke, G.M.
1981: The Palabora complex -- triumph over low grade ores; Industrial Minerals, Number 169, p. 45-62.

1984: The Torbed Process -- a new technique for mineral processing; Industrial Minerals, Number 207, p.57-59.
- Cunningham, L.J.
1969: Report on Olympus vermiculite deposit, North Burgess Township, Stanleyville, Ontario; Unpublished company report, G.H.D. Consultants, 19p.
- Deer, W.A., Howie, R.A., and Zussman, J.
1980: An introduction to the rock forming minerals, Longman Group Limited, London, England, p. 528.
- De Kimpe, C.R. and Miles, N.M.
1988: Geographic distribution of corrensite and associated minerals in southeastern Ontario; Can. Minerals (in press).
- De Kimpe, C.R., Miles, N.M., Kodama, H., and Dejou, J.
1987: Alteration of phlogopite to corrensite at Sharbot Lake, Ontario; Clays Clay Miner 35, p. 150-158.
- Dickson, E.M.
1981: Industrial Mineral Refractories Survey 1981, pp. 151-157.
- Dickson, T.
1982: Vermiculite -- little growth envisaged; Industrial Minerals, Number 179, p. 47-51.

- Dodson, C.E.
1986: The Torbed process -- An overview; Industrial Minerals (July) Supplement, p. 32-35.
- Dugas, J.
1950: Perth map-area, Lanark and Leeds Counties, Ontario (summary account); Department of Mines and Technical Surveys, Geological Survey of Canada, Paper 50-29, 19p.
- Globe and Mail
1984: Silicon-based products that mimic plastic emerge; March 30, 1984.
- Guillet, G.R.
1962: Vermiculite in Ontario; Industrial Mines Report 7, Ontario Department of Mines, 39p.
- Harben, P.W., and Bates R.L.
1984: Vermiculite; p. 282-284 in Geology of the Non-Metallics, Metal Bulletin Inc., New York, United States, 392p.
- Hitchins, J.W.
1970: Exfoliating vermiculite; Industrial Minerals, Number 38, p.17-19.
- Hoadley, J.N.
1960: Mica deposits of Canada; Department of Mines and Technical Survey, Geological Survey of Canada, Economic Geology Series Number 19, 141p.
- Holz, P.
1983: Vermiculite expands in more ways than one; Industrial Minerals, Number 192, p. 45-48.
- Imperial Chemical Industries (PLC),
Fortress T., heat resistant glass -- fibre non-woven tissue; (promotional pamphlet), Imperial Chemical Industries PLC, Mond Division England.
1984: 'M 729' Glass fabrics for high temperature use; promotional pamphlet, Imperial Chemical Industries PLC, Mond Division, England.
- Kretschmar, U.
1984: Geology and economic potential of the Prairie Lake Carbonatite; 8th Annual District Four Meeting, October, 1984, Thunder Bay, Ontario, Canadian Institute of Mining and Metallurgy, 28p.
- Lamothe J.M. and Wang S.S.D.
1986: Beneficiation of vermiculite samples from Stanleyville, Ontario; Mineral Sciences Laboratories

Divisional Rept. MSL 86-18 (1R), CANMET, Energy Mines and Resources, 21p.

Libby, S.C.

- 1975: Origin of potassic ultramafic rocks in the Enoree vermiculite district, South Caroline; Ph.D. Thesis, Pennsylvania State University.

Mandoval Ltd.

- 1972: Vermiculite and its properties; promotion pamphlet 6th Ed., Mandoval Ltd., 6 St. James Square, London, England, SW1Y 4LD.

Meisinger, A.C.

- 1980: Vermiculite; p.1015-1024 in Mineral facts and problems 1980 Edition, United States Bureau of Mines Bulletin 671, 1060p.
- 1983: Vermiculite; United States Minerals Yearbook, 1982. pp. 1-3.
- 1985: Vermiculite; p.172-173 in Mineral commodity summaries 1985, United States Bureau of Mines, 185p.
- 1986a: Vermiculite; A chapter from mineral facts and problems 1985 Edition, United States Bureau of Mines preprint from Bulletin 675, pp 1-6.
- 1986b: Vermiculite; p.174-175 in Mineral commodity summaries 1986, United States Bureau of Mines, 187p.
- 1987a: Vermiculite; United States Minerals Yearbook 1986, United States Bureau of Mines preprint, pp.1-4.
- 1987b: Vermiculite; p. 176-177 in Mineral commodity summaries 1987, United States Bureau of Mines, 189p.

Miles, N.M., and Springer, J.S.

- 1989a: Post-metamorphic hydration in Grenvillian rocks, southeast Ontario: Tectonic setting and limiting ages (Abstract); paper presented at the GAC Meeting, May 1989, Quebec City, (in press).
- 1989b: A rare interstratified phyllosilicate from vermiculite, Stanleyville Ontario (Abstract); paper presented at the GAC Meeting, May, 1989, Quebec City, (in press).

Miles, N.M., and DeKimpe, C.R.

- 1983: Significance of corrensite in soils of southeastern Ontario; Canadian Journal Soil Sciences 68, p.617-627.

Morgan, G.A.

- 1987: The mineral industry of the Republic of South Africa, United States minerals yearbook 1986, (preprint), p.1-23.

Ontario Geological Survey

- 1983: Cavendish Township, Peterborough County; Ontario Geological Survey, Geological Data Inventory Folio 60, compiled by staff of the Resident Geologist's Office, Bancroft, 52p. and 3 maps.

Myers, J.B.

- 1960: , in Industrial Mineral and Rocks, Seeley W. Mudd Series, 3rd Edition.

Power, T.

- 1986: Perlite & vermiculite- the market overlap; Industrial Minerals Number 230, p. 39 - 49.

Rose, E.R.

- 1958: Iron deposits of eastern Ontario and adjoining Quebec; Geological Survey of Canada, Bulletin 45

Statistics Canada

- 1987: Non-metals: Import trade for 1985 to 1987, pp.1.
1988: Vermiculite crudes, Imports Statement Month 12, Dec. 1987

Strand, P.R. and Steward, O.F.

- 1983: Vermiculite; p.1375-1378 in Industrial Minerals and Rocks, Edited by S.J. Leford, American Institute of Mining, Metallurgical and Petroleum Engineers, Inc., USA, 5th Edition, Volume 2, p.722-1445.

The Mining Journal

- 1954: Properties and occurrences of vermiculite; The Mining Journal, Volume 242, Number 6177, p.46-47.

The Vermiculite Association Inc.

- American vermiculite; Vermiculite Insulating Ltd. promotional pamphlet, 1775-52nd. Avenue, Lachine, Quebec, H3T 2Y1, 15p.

Torftech Ltd.

- 1983: The Torbed 700 vermiculite exfoliator; Torftech Ltd. promotional pamphlet, P.O. Box 133, 6 St. James Square, London, England SW1Y 4LD, 2p.

1984: The Torbed process-an overview; Torftech Ltd. promotional pamphlet, Mortimer Hill, Mortimer, Reading, Berkshire, RG7 3PG, 2p.

Vagt, O.

- 1988: Mineral Aggregates; p. 44.1-44.11 in Canadian Minerals Yearbook 1987- Review and Outlook, Edited by

G.E. Thompson and G. Cathcart, Energy Mines and Resources Canada.

Williams, D.A., and Wolf, R.R.

1984: Paleozoic geology of the Perth area, southern Ontario; Ontario Geological Survey, Map P2724, Geological Series - Preliminary Map, scale 1:50 000, Geology 1982.

Wilson, A.E., Brownell, G.M., and Wynne-Edwards, H.R.

1967: Westport; Geological Survey of Canada, Map 1182A, Scale 1:63 680 or 1 inch to 1 mile.

Wilson, H.S.,

1957: Report on milling tests of vermiculite received from Northern Vermiculite Limited, Perth, Ontario; Canada Mines Branch Investigation Report IM No. 452, Ottawa, 7p.

1961: Investigation of vermiculite - bearing samples from Olympus Mines Ltd., Stanleyville, Ontario; Canada Mines Branch Investigation Report IR 61-39, Ottawa, 19 p.

1969: Assessment of vermiculite-bearing drill core samples from Stanleyville, Ontario; Canada Mines Branch Investigation Report IR 69-84, 8p.

1981: Lightweight aggregates-vermiculite, perlite, pumice-for insulating concretes; Canmet Report 81-15E, Minerals Research Program, Mineral Sciences Laboratories, Energy, Mines and Resources Canada, 28p.

Wilson, M.E., and Dugas, J.

1961: Perth; Geological Survey of Canada, Map 1089A, scale 1:63 680 or 1 inch to 1 mile, with descriptive notes.

Wolfson, I.R.

1980: A geological study of the Olympus vermiculite pit near Stanleyville, Ontario; unpublished BSc. thesis, Queen's University, Kingston, Ontario, 16p.

W.R. Grace & Co.

1971: Zonolite brand vermiculites -- Properties and uses; promotional pamphlet, Construction Products Division, W.R. Grace and Company, 62 Whittemore Avenue, Avenue, Cambridge, Massachusetts 02140, United States 11p.

Wyman, R.A.,

1964: Beneficiation tests on vermiculite from Stanleyville, Ontario (Project MPIM 6219); Canada Mines Branch Investigation Report IR 64-66, Ottawa, 19p.

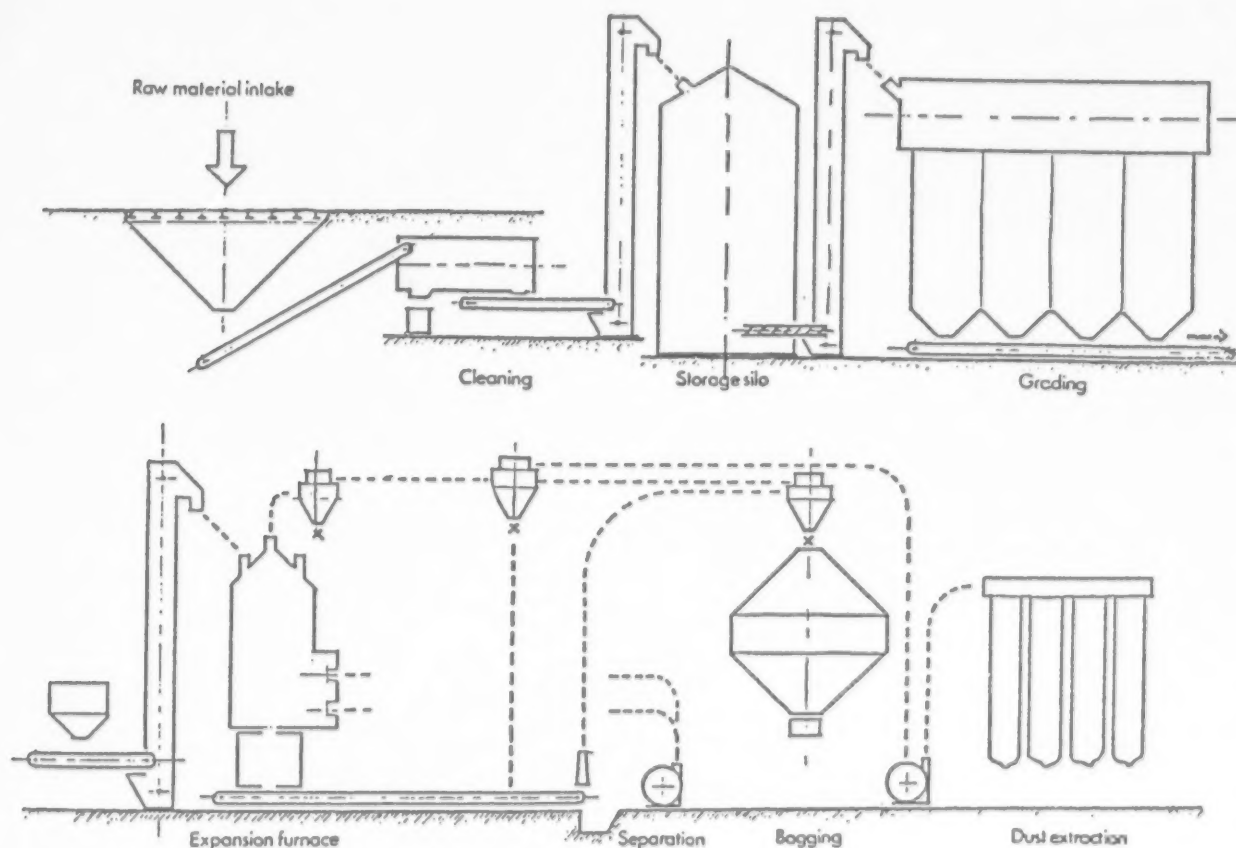
Wynne-Edwards, H.R.

1967: Westport map area with special emphasis on the
Precambrian rocks; Geological Survey of Canada,
Memoir 346, 142p.

APPENDIXES

APPENDIX A:

Figure 10, Flow chart of a typical expanding plant



(after Hitchins 1970)

A suitable and economic exfoliation process for the type and grade of vermiculite is extremely important. Figure , illustrates a typical vermiculite expanding plant flow plan. Raw material is received into the plant, cleaned of shipping and cartage debris and stored in the buffer-stock silo. The rate of grading is geared as closely as possible to production requirements, to avoid unnecessary handling (Hitchins, 1970). The sized fractions are individually exfoliated using either a

rotary, cascade, vibrating tray or injection tray-type furnace, typically at a rate of 1 ton/hr. Figure 11, is a schematic diagram of a vertical section of a typical furnace currently being employed. Upon entering the furnace the ore is spread by the baffles, then heated between 850°C and $1,100^{\circ}\text{C}$ where it is exfoliated; typical retention time is 5-10 seconds. (Wilson, 1981). The vermiculite is removed by suction fan into a classifier system to collect the product and remove excess fines. The sized, exfoliated vermiculite is usually packaged into 4 cubic foot bags, each weighing between 7 and 14 kg depending on the grade (finer grades being heavier).

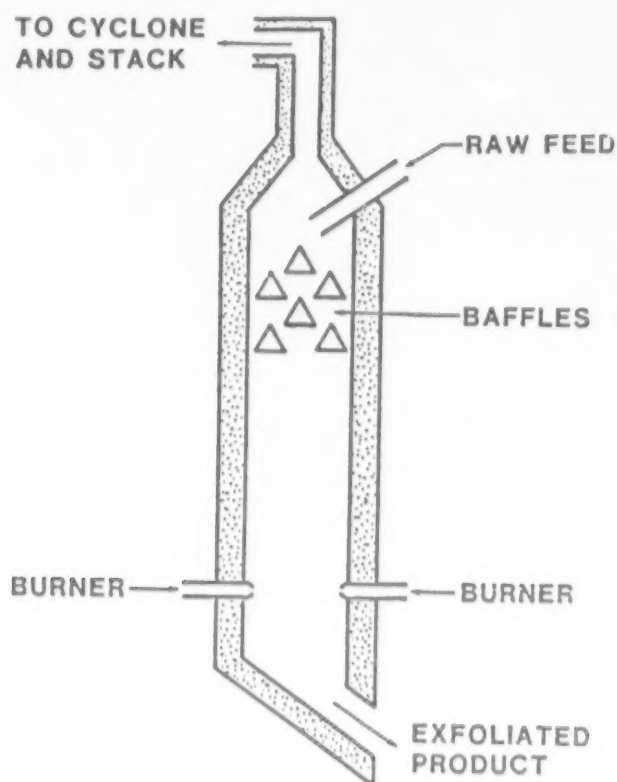


Figure 11, Schematic section of a vertical furnace (from Wilson 1981).

APPENDIX B

CAVENDISH TOWNSHIP

Goshawk Mines Ltd. Vermiculite Property

Location and Access: The property is located approximately 56 km north of Peterborough, Ontario on parts of lots 19-23, concessions III and IV, Cavendish Township, Peterborough County. NTS 31D/9.

Highway 507 runs within 3.2 km of the property and cottage roads from this highway bisect the claim group. The claim group consists of eleven wholly owned contiguous unpatented claims; bounded on the north by Catchacoma Lake, the east by Catchacoma Narrows and on the south by Mississauga Lake (Archibald 1976; 1977a, 1977b)

History

Vermiculite was first discovered and subsequently staked in 1950 by H.G. Greene. Periodically the property was test-pitted and stripped in a haphazard manner, mainly over the east end of the claim group.

Globex Minerals Inc. leased the ground in 1973 and during 1974 conducted limited auger and diamond drilling.

In 1975, Goshawk Mines Ltd. purchased 100% interest in the claims. During 1975-1977 the company conducted a exploration programme which included trenching, power augering, diamond drilling and soil sampling.

Geology

The geology of the property is shown in Figure 12 and described by Archibald (1977b) as follows:

"The claim group is underlain mainly by Grenville limestone which has been altered to a marble. Areas can be seen in this marble with disseminated flakes of amber coloured mica which has been altered to pseudo-vermiculite and vermiculite. In some areas, the mica is heavily concentrated in thick, flat dipping bands of schist, locally striking east-west.

To the south, the claim group overlies the Anstruther granite batholith in the form of granite gneiss. Bordering this mass is a band of dark paragneiss, which has been altered to biotite schist and amphibolite. Narrow lenses of this amphibolite are also found within the marble.

The limestone occurs as a series of east-west trending ridges with steep north faces and gentle south dipping slopes. This bedding varies from flat lying to thirty degrees, dipping generally to the south.

In areas of vermiculite-rich limestone, the tops of the ridges appear to have weathered in place to an average depth of ten feet, leaving many of the lower depression areas in relatively unweathered state due to the protection afforded by the high ground water table. These depressions are often filled with concentrations of loose, raw vermiculite that has migrated off the nearby hillside."

Flakes are up to 1/2 inch in diameter but generally less than 1/8 inch; and vary from amber, green, and black, to silver in colour.

Augering and diamond drilling has indicated that the largest concentration of vermiculite lies in the free state near surface; three zones were roughly defined (Zone A, Zone B, Zone C). Zone A covers an area 457 m (1500 ft.) long by 122 m (400 ft.) wide on the east side of the property. Exploration primarily concentrated on this (54,500 tons or 93,309 cu. yds.) zone. Archibald (1977a) estimated that a minimum of 49,400 tonnes of vermiculite, averaging 11.9% exfoliated vermiculite was contained

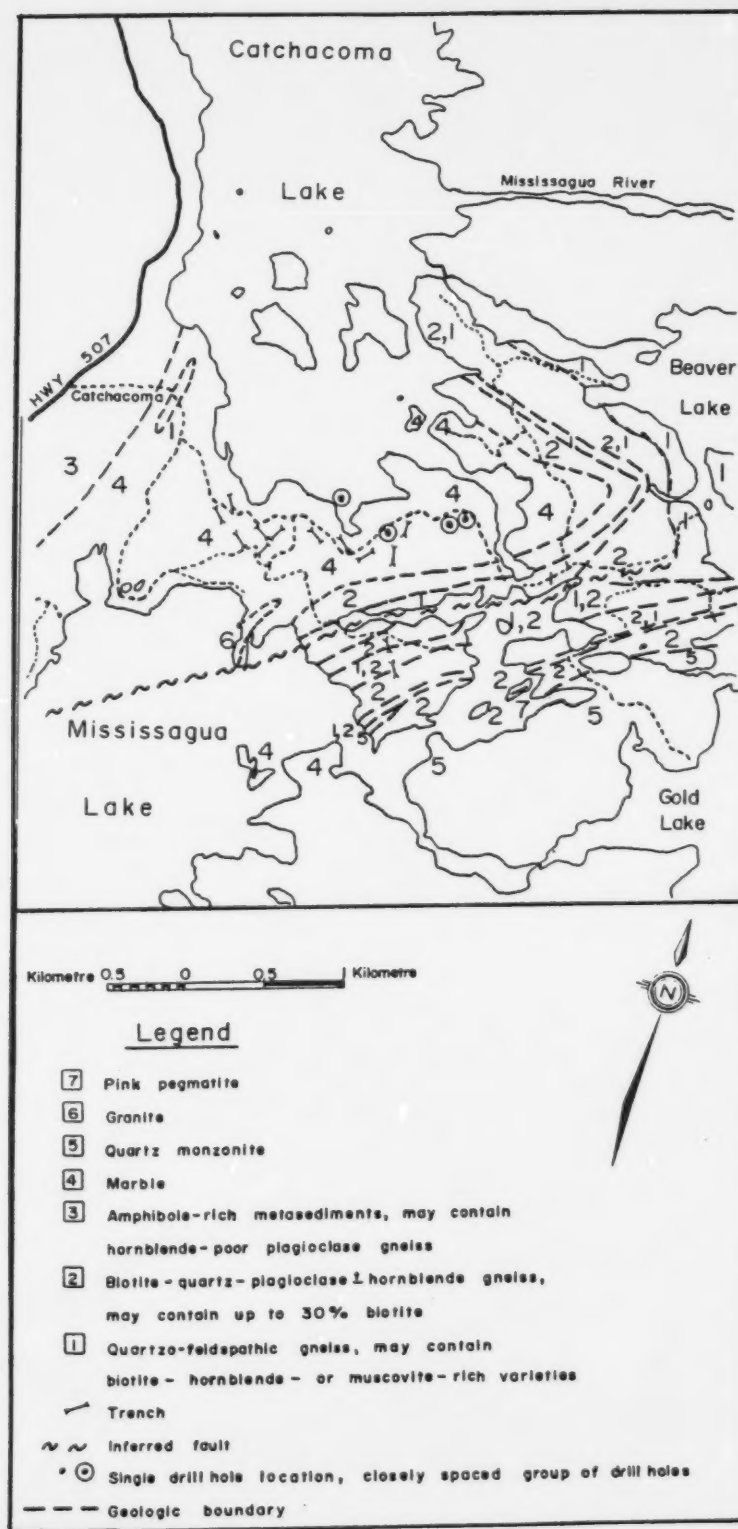


Figure 12, Geology of the Goshawk Mines Ltd. property
(after Bright 1981, OGS 1983)

within the topsoil. Zone B consists of four separate bodies over a strike length of 610 m (2,000 ft.) in the central portion of the property. Zone C is located at the west end of the property and appears to be fairly good grade vermiculite (Archibald 1977b). Sufficient work was not conducted on Zones B and C to fully access them.

The concentration of vermiculite in bedrock is generally less than 5%, and decreases with depth.

Comments

Testing conducted by Goshawk Mines Ltd. has indicated that the vermiculite does not absorb water (low wetability), as a result, it is unsuitable for agricultural purposes. However, this quality is desirable for use as insulation, in wallboard, plasters and similar products which cannot tolerate moisture; but, since the exfoliated material is fine-grained, it would only be applicable for wallboard or plaster aggregate. The bulk density of the majority of the material is a little too high for current specifications but should this problem be overcome, the deposit is in a favourable location to compete for domestic markets.

APPENDIX C:

G.H.D. Consultants of Toronto 1969 Drill Log Results

PROPERTY: Olympus Vermiculite Deposit
N. Burgess Twp. Stanleyville

HOLE NO.: W.E. 1

LOCATION: 100' NW of pit & 200' SW of the NE end of the pit

LATITUDE: STRIKE: S 45° E PAGE NO.:

DEPARTURE: DIP: 45°

ELEVATION: DATE DRILLED: 16-19 Sept. 1969

PURPOSE: To test for vertical continuity below pit

FOOTAGE	DESCRIPTION	SAMPLE NO.	WIDTH	ASSAY VALUE
0- 9	CASTING			
9- 72	METAMORPHIC PYROXENITE - broken & weathered			
72- 78	DARK BASIC DIKE - light hematite staining in dike and walls			
78-124	METAMORPHIC PYROXENITE - massive, motley coloured grey-green with brown vermiculite flakes low grade vermiculite + 5% increase in vermiculite around 110			
124-263	VERMICULITE RICH - metamorphic pyroxenite			
124-133		5401	9'	
133-143		5402	10'	
143-153	FINE FLAKES - estimated + 20%	5403	10'	
153-161		5404	8'	
161-170		5405	9'	
170-180		5406	10'	
180-190	PATCHY - + 15%	5407	10'	
190-200		5408	10'	
200-209	)	5409	9'	
209-219	)	5410	10'	
219-228	)	5411	9'	
228-237	)	5412	9'	
237-247	)	5413	9'	
247-256	)	5414	10'	
256-266	) UNIFORM	5415	9'	
266-276	) FINE GRAINED	5416	10'	
276-285	)	5417	9'	
285-295	) + 20%	5418	10'	
295-305	)	5419	10'	
305-314	)	5420	9'	

314-323	)	5421	9'
323-333	)	5422	10'
333-342	)	5423	9'
342-352	)	5424	10'
352-362	)	5425	10'

362-501 METAMORPHIC PYROXENITE - Massive -
green-grey occasional short section
showing ± 5% vermiculite

end of hole.

PROPERTY: Olympus Vermiculite Deposit
N. Burgess Twp. Stanleyville

HOLE NO.: W.E. 2

LOCATION: 100' NW of pit & 500' SW of the NE end of pit

LATITUDE: STRIKE: S 45° E PAGE NO: 1/2

DEPARTURE: DIP: 45°

ELEVATION: DATE DRILLED: 20-23 Sept., 1969

PURPOSE: To test for vertical continuity beneath pit

FOOTAGE	DESCRIPTION	SAMPLE NO.	WIDTH	ASSAY VALUE
0- 35	CASING			
35- 70	METAMORPHIC PYROXENITE - vermiculite poor; generally light coloured: white-grey-cream-green with bands estimated vermiculite content $\pm$ 5% Poorly banded 60° /core,			
70- 93	METAMORPHIC PYROXENITE - pale green			
93- 98	METAMORPHIC PYROXENITE - $\pm$ 15% vermiculite fine brown flakes			
98-107	METAMORPHIC PYROXENITE - white to dark grey			
101-160	METAMORPHIC PYROXENITE - massive motley mixture of green, white & brown minerals brown - vermiculite green - pyroxenite white - carbonate 10w grade vermiculite $\pm$ 5% vermiculite			
153-370	AS ABOVE - but increase in vermiculite appearing as seams, bands and patches - core lighter in colour			
153-160		5448	7'	
160-170	light coloured generally fine	5426	10'	
170-180	vermiculite with patches of	5427	10'	
180-190	coarse vermiculite $\pm$ 15%	5428	10'	
190-200		5429	10'	
200-210		5430	10'	
210-220	light coloured - fine	5431	10'	
220-230	vermiculite with coarse patches	5432	10'	
230-240	$\pm$ 10%	5433	10'	
240-249		5434	9'	
249-259	dark brown colours - crystalline;	5435	10'	
259-269	estimated 25% but maybe	5436	10'	

269-278	considerable mica present	5437	9'
278-287		5438	9'
287-296		5439	9'
296-306	light coloured - finely	5440	10'
306-316	disseminated vermiculite <u>+</u> 15%	5441	10'
316-325		5442	9'
325-336		5443	9'
336-345		5444	9'
345-354		5445	9'
354-364	dark, patchy - + 10%	5446	10'
364-370			
370-425	metamorphic pyroxenite massive hard, motley-green to white		
425	end of hole		

PROPERTY: Olympus Vermiculite Deposit
N. Burgess Twp. Stanleyville

HOLE NO.: W.E. 3

LOCATION: 50' NW of pit & 800' SW of NE end of pit

LATITUDE: STRIKE: S 45° E PAGE NO.:

DEPARTURE: DIP: 45°

ELEVATION: DATE DRILLED: 23-25th Sept. 1969

PURPOSE: To test for vertical continuity below pit

FOOTAGE	DESCRIPTION	SAMPLE NO.	WIDTH	ASSAY VALUE
0- 38	CASING			
38- 85	METAMORPHIC PYROXENITE motley colour brown green & white vermiculite + 5%			
85-180	METAMORPHIC PYROXENITE vermiculite rich			
	85 - 95)	5449	10'	
	95 - 105)	4450	10'	
	105 - 115) Finely flaked + 20%	51	10'	
	115 - 125)	52	10'	
	125 - 135) Patchy lean & rich	53	10'	
	135 - 145) sections + 20%	54	10'	
	145 - 155)	55	10'	
	155 - 165) Finely disseminated	56	10'	
	165 - 173) + 25%	57	8'	
	173 - 180)	58	7'	
180-200	METAMORPHIC PYROXENITE Motley coloured brown, green white vermiculite + 5%			
200-230	METAMORPHIC PYROXENITE vermiculite rich			
	200-210)	5459	10'	
	210-220) Patchy some coarse	60	10'	
	220-230) material + 15%	61		
230-410	METAMORPHIC PYROXENITE motley coarse massive - green brown grey little or no vermiculite			
410-440	METAMORPHIC PYROXENITE vermiculite poor light coloured + 5%			
440-455	METAMORPHIC PYROXENITE light coloured little or no vermiculite			
455	END OF HOLE			

PROPERTY: Olympus Vermiculite Deposits
N. Burgess Twp. Stanleyville

HOLE NO.: W.E. 4

LOCATION: 550' N 45° E of Hole #1 at toe of stock pile

LATITUDE: STRIKE: S 45° E PAGE NO.:

DEPARTURE: DIP: 42°

ELEVATION: DATE DRILLED: 25-29 Sept. 1969

PURPOSE: To test the zone north easterly from pit

FOOTAGE	DESCRIPTION	SAMPLE NO.	WIDTH	ASSAY VALUE
0- 23	CASING			
23- 28	METAMORPHIC PYROXENITE - reddish rock with hematite			
28- 90	METAMORPHIC PYROXENITE - motley dark green to grey with stringers of carbonate & poor bedding @ 60% core occasional section - blue talcose rock minor vermiculite developed around footage 95			
90-304				
90- 95	Gradational change to light coloured limy rock - motley appearance - often pearly grey to green with minor vermiculite & other micaeous minerals developed. Vermiculite in patches & less than 5% in small flakes narrow ribbon of dark talc 270-304 - increase in vermiculite but still + 5%			
304-313	Banded VERMICULITE RICH PYROXENITE 15-20%	5462	9'	
313-322	Banded VERMICULITE RICH PYROXENITE 20-25%	63	9'	
322-323	1 foot talc blue green			
323-332	Banded VERMICULITE RICH PYROXENITE + 20%	64	9'	
332-341	60-80°/core	65	9'	
341-351	Banded VERMICULITE RICH PYROXENITE + 20%	66	10'	
351-361	Banded VERMICULITE RICH PYROXENITE	67	10'	
361-372	-70°/core	68	11'	
372-383	Banded VERMICULITE RICH PYROXENITE + 20%	69	11'	
383-392	Banded @ 70° VERMICULITE RICH PYROXENITE + 20%	70	9'	
392-405	Banded VERMICULITE RICH PYROXENITE	71	7'	
405-415	TALCOSE PYROXENITE dark green with			

	light green sections no vermiculite		
415-425	VERMICULITE Poor metamorphic pyroxenite + 15%	72	10'
425-435	VERMICULITE Poor metamorphic pyroxenite + 15%	73	10'
435	rich rich + 20%	74	10'
435-445	VERMICULITE metamorphic pyroxenite + 20%	75	10'
445-457	VERMICULITE rich rich + 20%	76	12'
457-471	dark PYROXENITE with limy bands may include altered basic dike		
471-478	Banded Vermiculite poor metamorphic pyroxenite + 15%		
478-488	Banded Vermiculite alternate rich & poor bands metamorphic pyroxenite + 15%		
488-496	Banded Vermiculite rich Metamorphic pyroxenite + 15%		
496-515	METAMORPHIC PYROXENITE green to black without vermiculite except: 501-505 vermiculite rich zone + 25%		
515	END OF HOLE		

VERMICULITE PROPERTY OF OLYMPUS MINES LIMITED

NORTH BURGESS TOWNSHIP, LANARK COUNTY
LOT 17, CONCESSION VIII

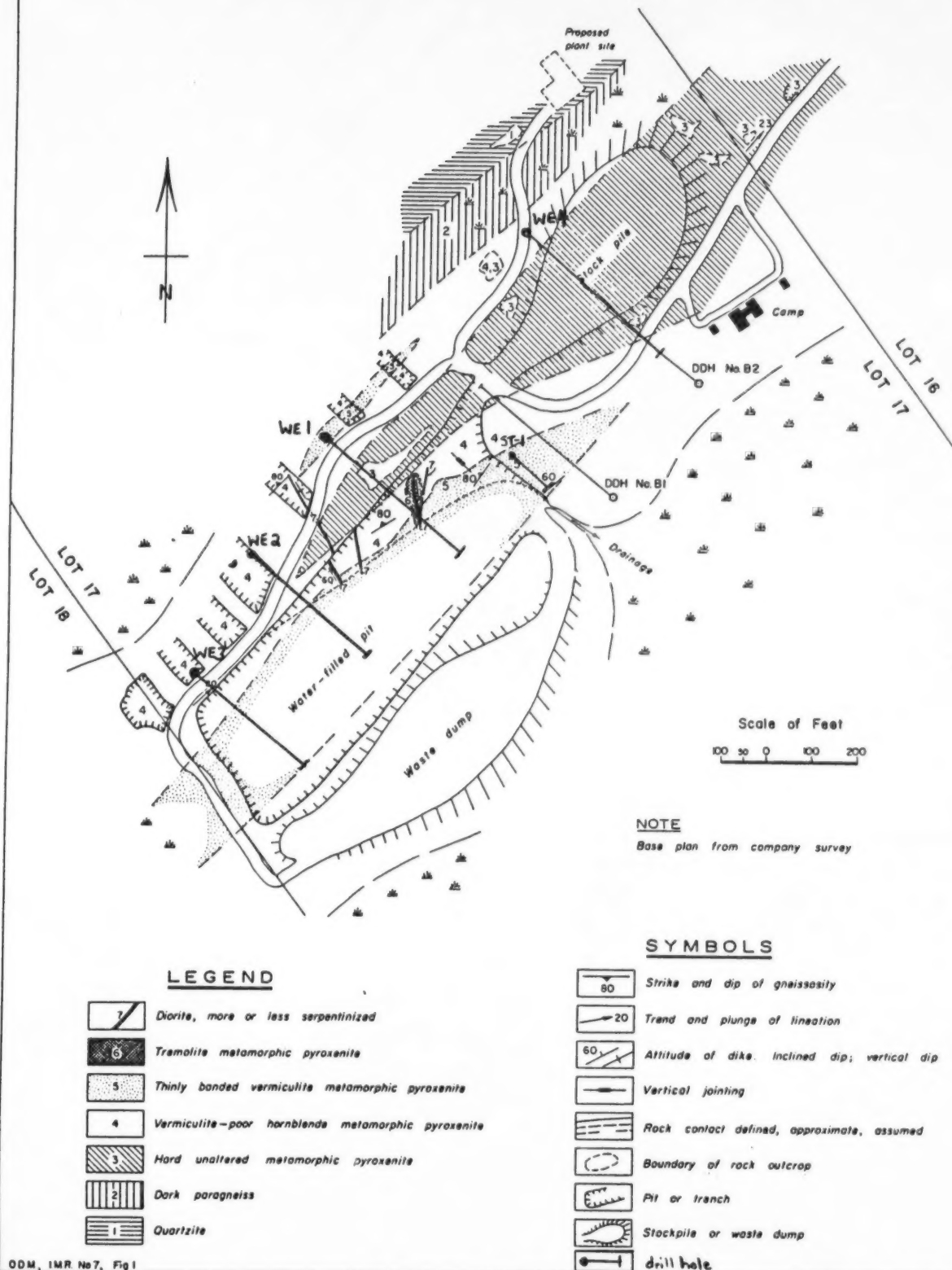
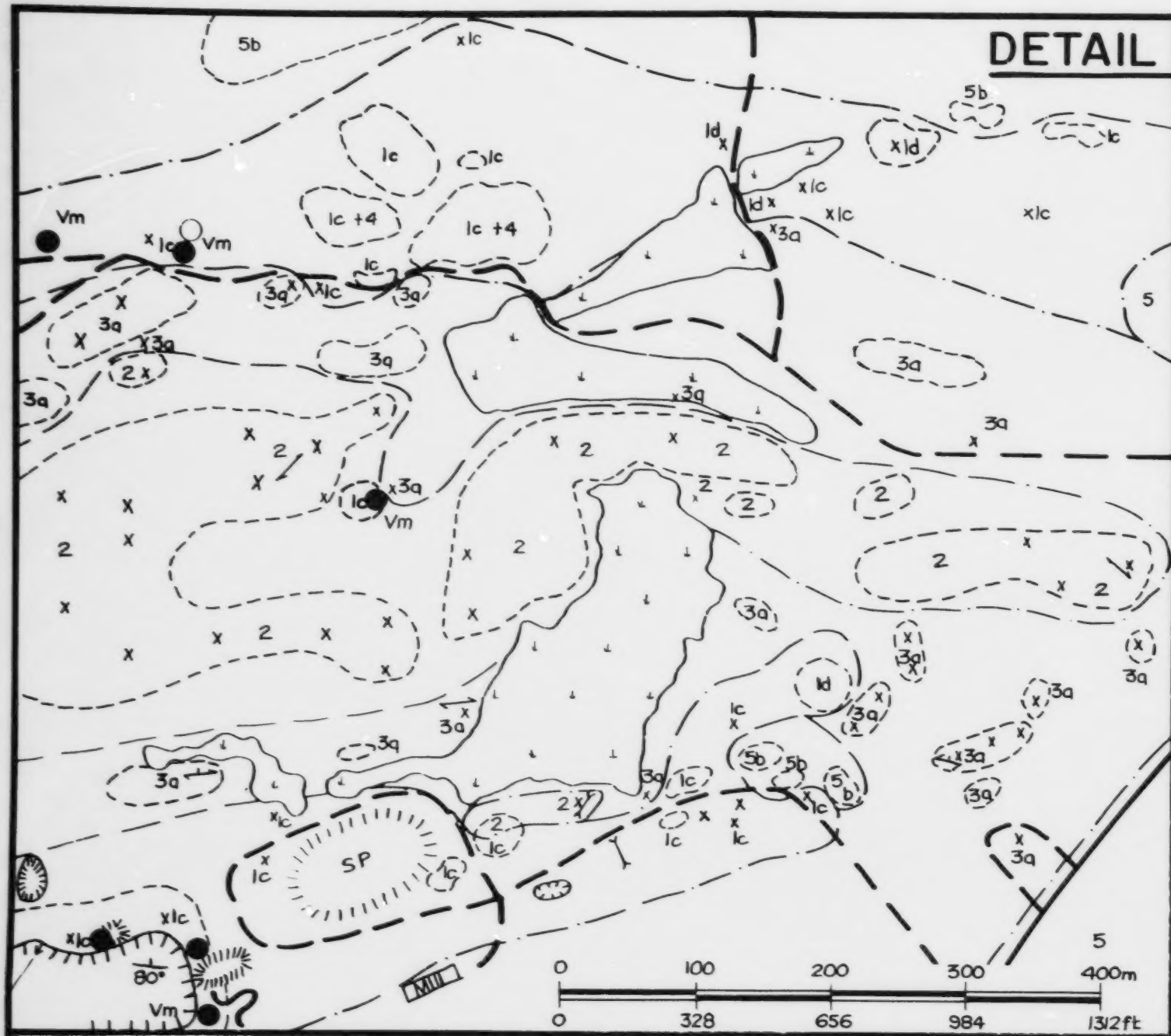


Figure 13, Drill hole location map (after Cunningham 1969, Guillet 1962).

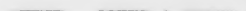
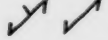
3268
ISSN 0826-9580
ISBN 0-7729-5337-6



STANLEYVILLE VERMICULITE OCCURRENCES

NORTH BURGESS TOWNSHIP

MAP LEGEND

-  Pit
-  Dump
-  Stock pile
-  Geological boundary (defined, assumed)
-  Rock outcrop, outcrop boundary
-  Vermiculite in place, in soil
-  Open cut
-  Trench
-  Schistosity, gneissosity, cleavage, foliation (inclined, dip unknown)
-  Bedding, tops known (inclined)

GEOLOGY LEGEND

PHANEROZOIC

CENOZOIC

QUATERNARY

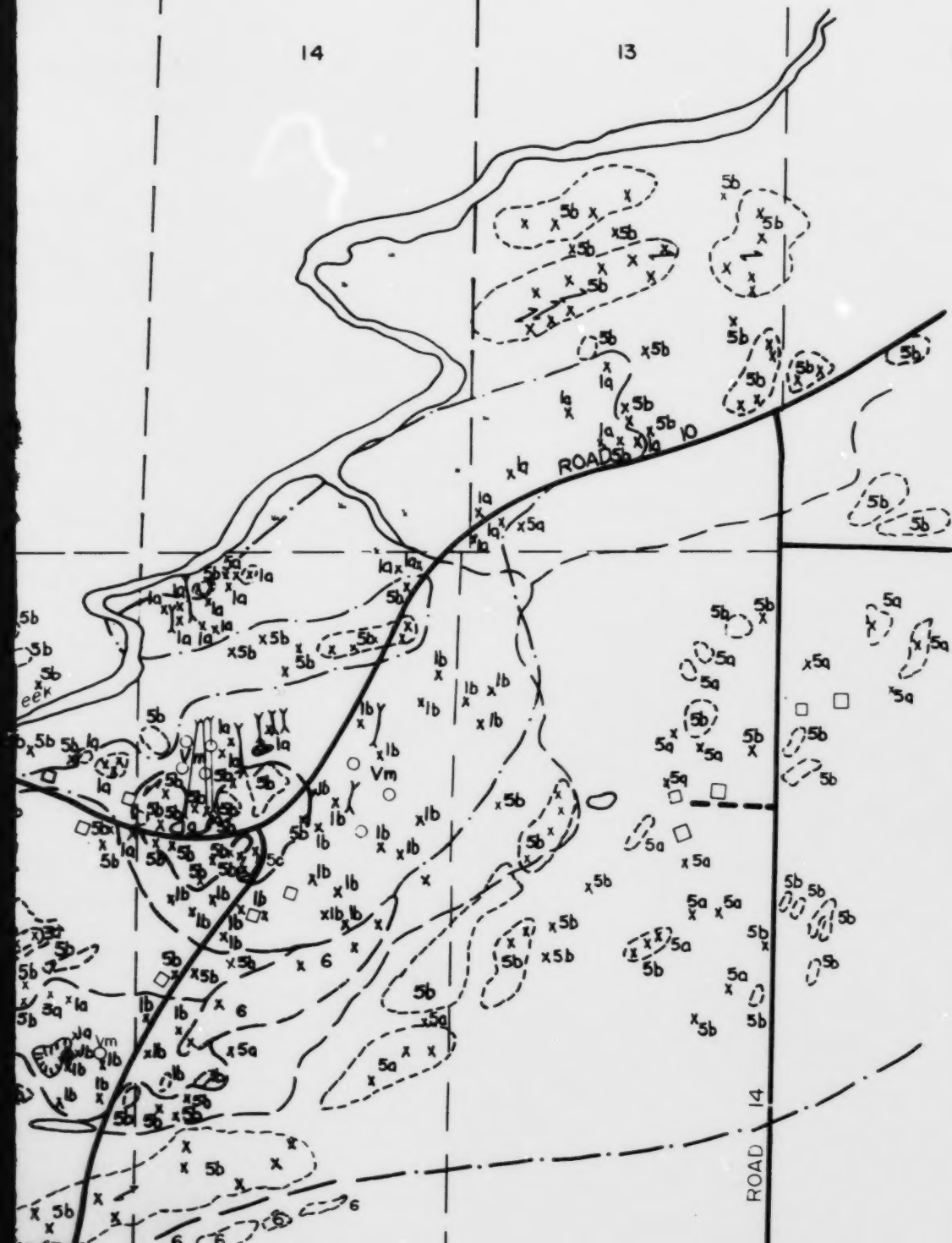
PLEISTOCENE AND RECENT
sand, gravel, clay, erratics

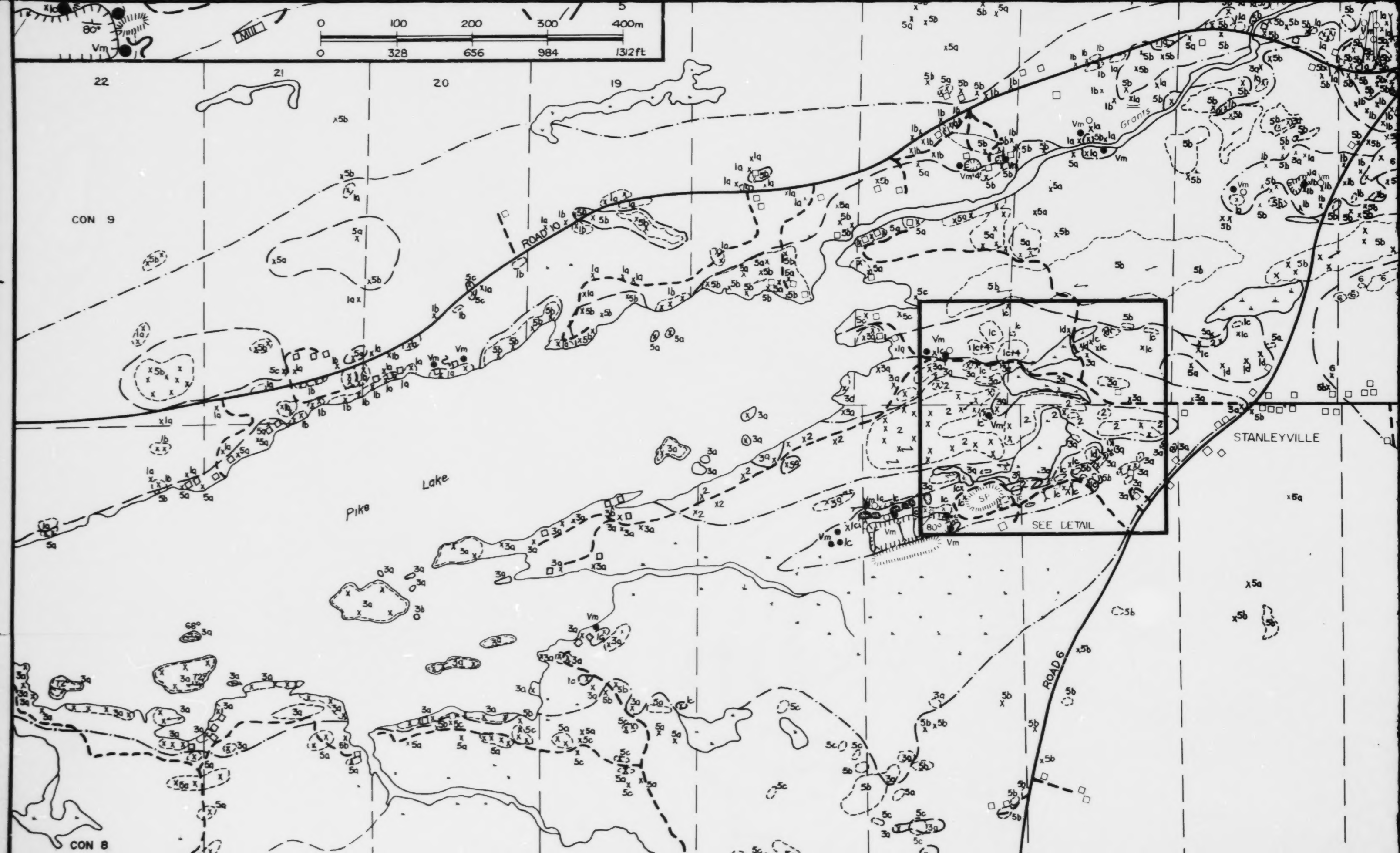
UNCONFORMITY

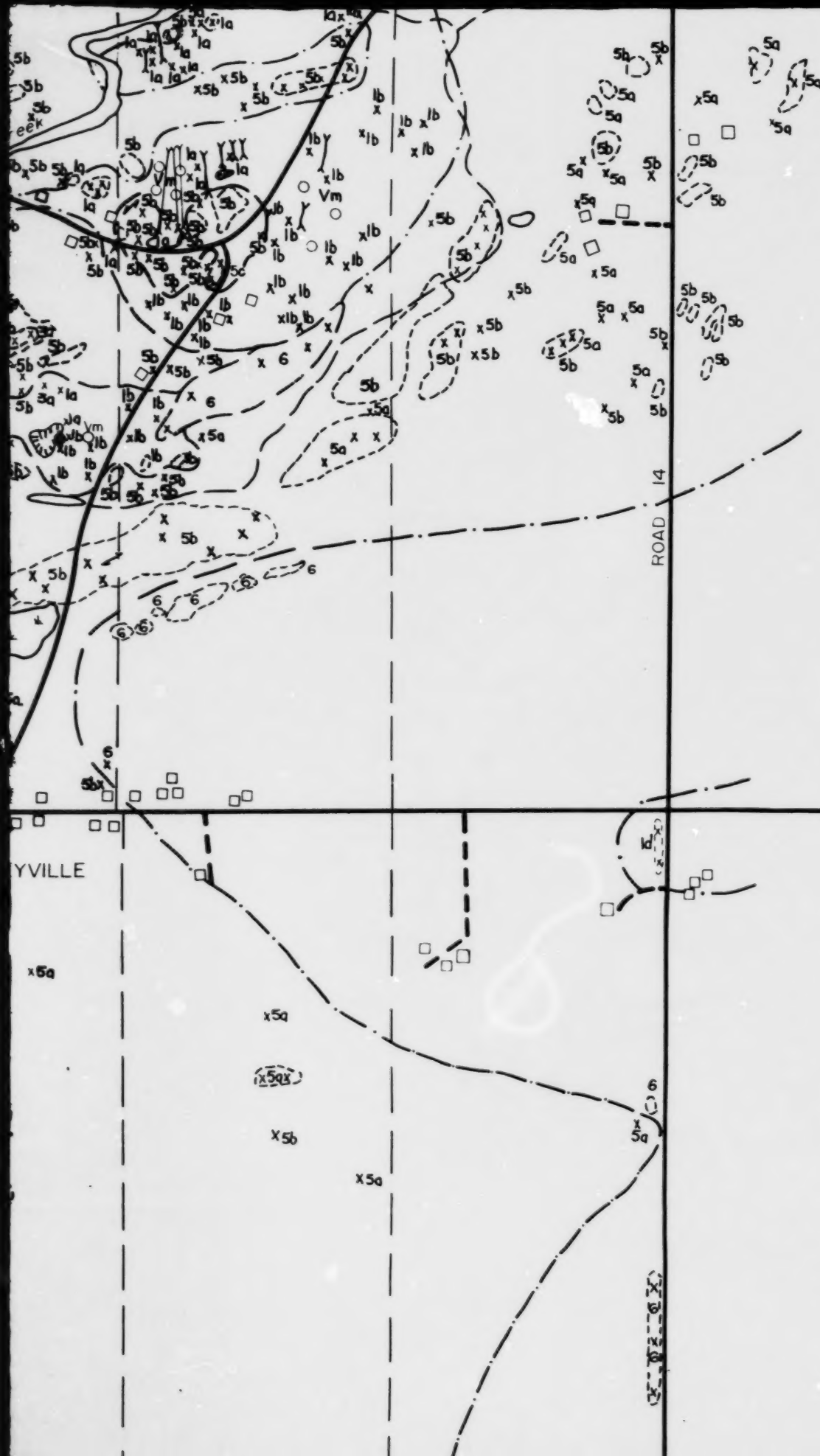
PALEOZOIC

CAMBRO - ORDOVICIAN

Nepean Formation; quartz sandstone







Bedding, tops known (inclined)

GEOLOGY LEGEND

PHANEROZOIC

CENOZOIC

QUATERNARY

PLEISTOCENE AND RECENT

sand, gravel, clay, erratics

UNCONFORMITY

PALEOZOIC

CAMBRO - ORDOVICIAN

6

Nepean Formation; quartz sandstone

UNCONFORMITY

PRECAMBRIAN

LATE PRECAMBRIAN

FELSIC TO INTERMEDIATE INTRUSIVE ROCKS

5a

Granite; gneissic to massive texture, in places migmatitic, cut later by pegmatitic dykes.

5b

Syenite, quartz syenite, syenite migmatite; may contain remnants of paragneiss, cut later by pegmatitic dykes.

5c

Diorite.

MAFIC INTRUSIVE ROCKS

+4

Phlogopite dykes.

GRENVILLE SUPERGROUP METASEDIMENTARY ROCKS

Clastic Metasediments

3a

Quartzofeldspathic paragneiss; may contain garnet, pliotite and/or disseminated graphite.

3b

Hornblende feldspathic paragneiss; may contain garnet and minor biotite.

Quartzose Metasediments

2

Pure quartzite, paragneisses consisting of interbedded quartz and brown crystalline limestone, or interbedded tremolite-actinolite-talc and quartz.

Calcareous Metasediments

1a

Phlogopitic marble, dolomitized phlogopitic marble; white to buff in colour, fine to coarse grained, may contain disseminated graphite.

1b

Diopsidic marble, dolomitized diopsidic marble; white to buff in colour with serpentinization of some diopside grains.

